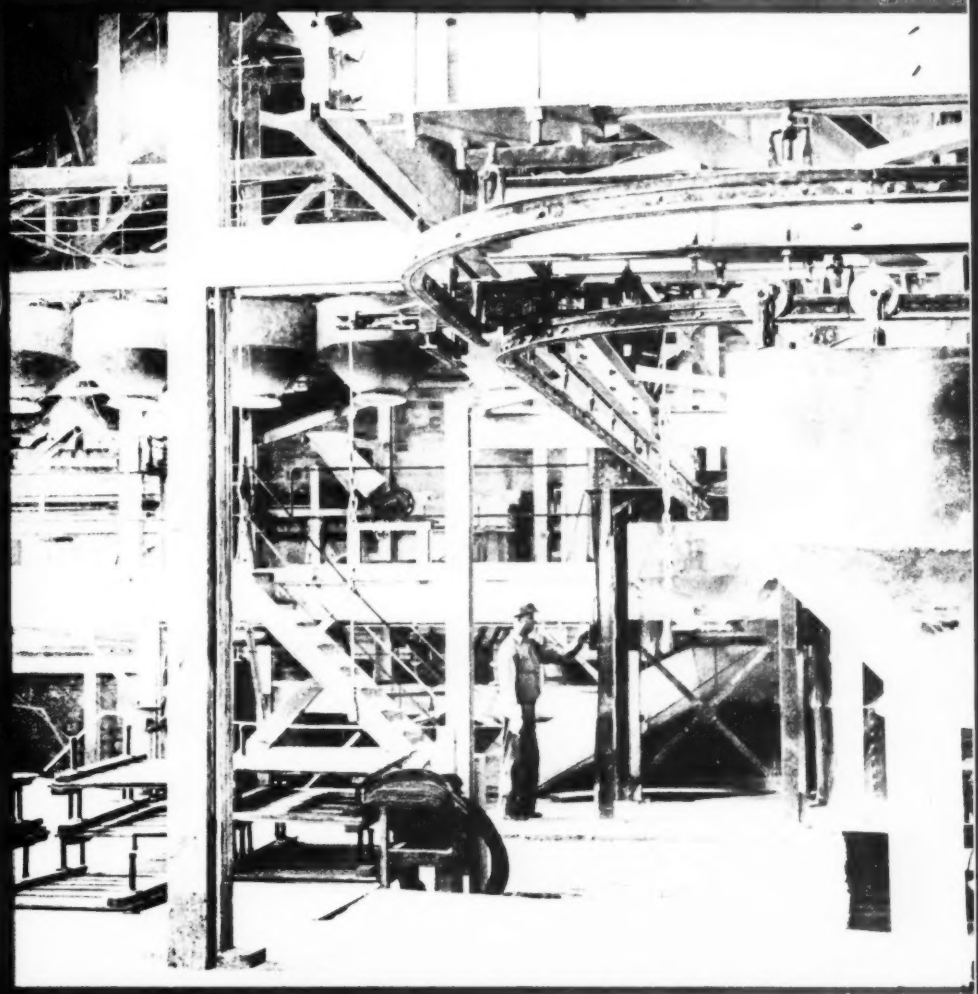
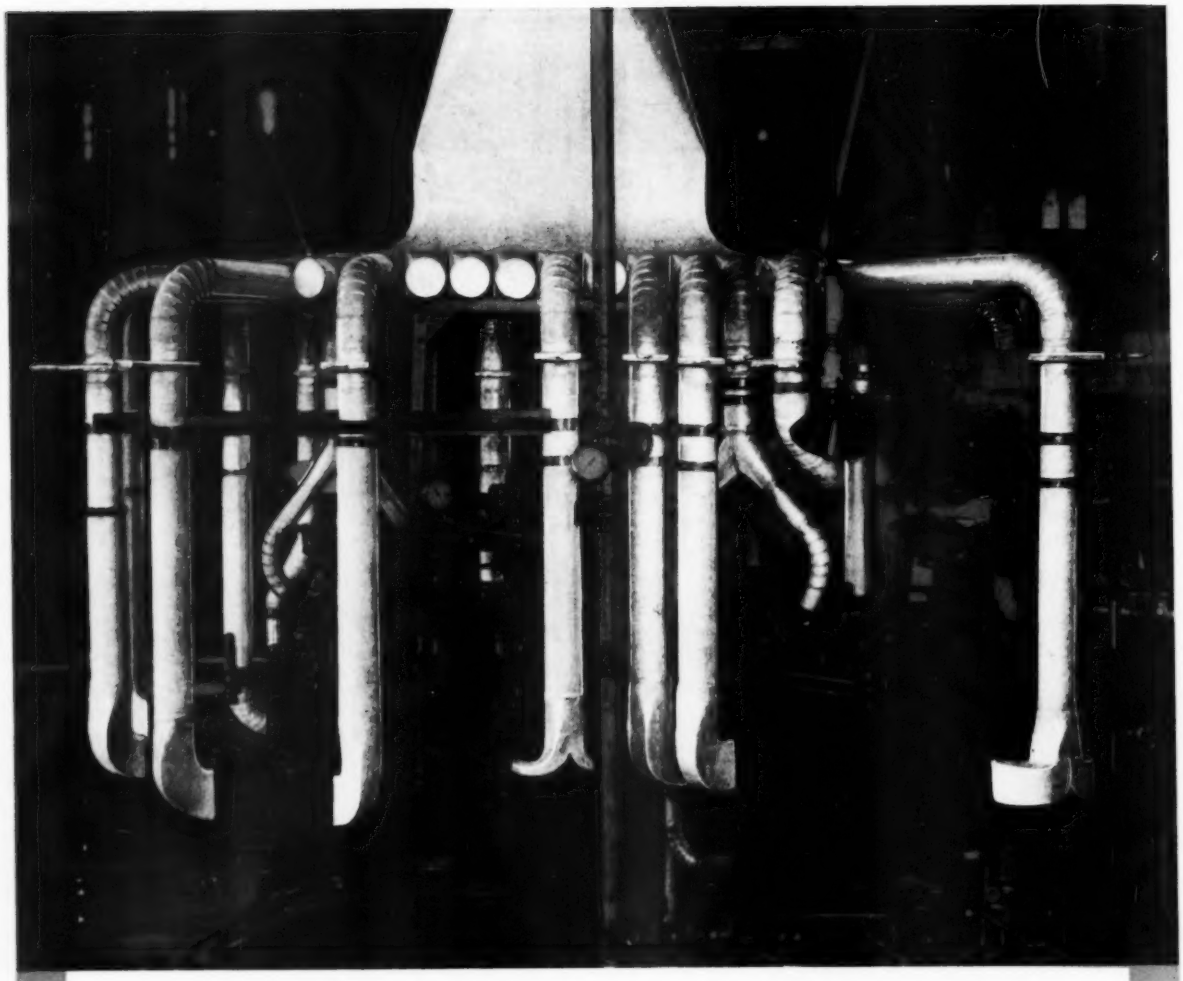
July, 1938

THE JOURNAL OF GLASS MANUFACTURING

the glass industry



Modern batch handling equipment as exemplified at the plant of the Sterling Glass Division of the Wallace Co., Capel, Indiana. The operator is standing at the lower push-button control of the elevator that raises the batch buckets to the charging floor. Details of the modernization of this plant are given on page 229.



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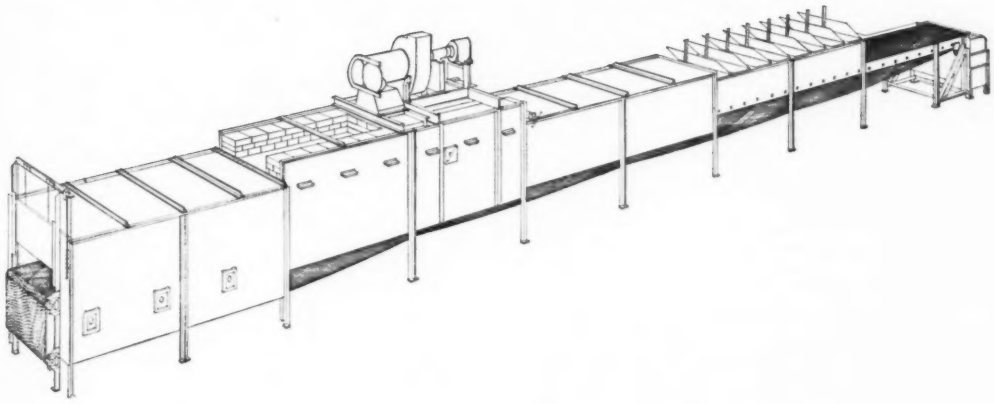

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the glass industry

Devoted to glass technology, engineering, material and glass factory equipment and operation

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● **The Role of Gases in Glass: I. Oxygen** **255**

This, the first of a series of three articles by Dr. Woldemar Weyl and A.G. Pincus of the Department of Ceramics, Pennsylvania State College, deals with the important role of oxygen. The next paper will summarize the part played by carbon dioxide.

● **Modernization of the Sterling Glass Plant** **259**

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The first of two articles by J. S. Vanick of the Research and Development Department of the International Nickel Co. deals with the action of nickel in several of the problems encountered in glass molds. Mr. Vanick will continue this discussion in August and will also make suggestions as to the grading and selection of cast iron, together with performance data.

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THE GLASS INDUSTRY

VOLUME 19, NUMBER 7, JULY, 1938

THE ROLE OF GASES IN GLASS: I. OXYGEN

By W. WEYL and A. G. PINCUS

Department of Ceramics, Pennsylvania State College

When visible as bubbles, gases in glass are an ever-present problem in all branches of the glass industry, as well as in ceramic glazes and enamels. Such bubbles obviously affect the appearance, light transmission, and strength of the final product. But the invisible, dissolved gases also play an important part in rate of vitrification, fining, color and decolorization, viscosity, tendency to devitrify, after-working and other characteristics of glasses. The purpose of the present series of papers is to discuss our present-day knowledge of the interactions between gases and glasses and the applications to glass-melting.

Gases are present because of the incomplete decomposition of certain batch materials or because the glass, being a supercooled liquid, remains supersaturated with the gases. In either case a state of non-equilibrium exists. Longer heating in the fining range would favor continual evolution of gases down to a theoretical equilibrium at nearly zero per cent gas content.

The analyses summarized in Table I indicate that oxygen, carbon dioxide, sulphur dioxide, and water are the most important gases occurring in glasses, and that the total gas content and the relative amounts of each gas vary widely with changes in basic composition. To go beyond this and be able to explain why this is so, in what form the gases are fixed, and under what conditions the equilibria are shifted, it is necessary to find some means to follow the invisible reactions in the melt. Among the means of bringing this about are:

(1) Meltings in a furnace permitting high pressures of the gas being studied.
(2) The use of coloring oxides as indicators.
(3) Manometric measurements of variations in the pressure of the evolving gas.
(4) Chemical analyses for special compounds of gas and oxide.
(5) Mineralization studies of induced crystallization.

The application of these principles will be brought out in the course of this discussion.

Oxygen distribution, particularly, can be followed very neatly with colored glasses. For instance, glasses containing manganese are nearly colorless or show a faint yellow when this element is present in its divalent state. As soon as the higher oxide is formed, a purple is developed the depth of which can be used as an approximate indicator of the position of the oxygen equilibrium. The color change from yellow (MnO) to purple (Mn_2O_3) is so sharp that this reaction can be used to follow the diffusion of oxygen into a glass and thus determine the diffusion speed at different temperatures. When we have to deal with colorless glasses the difficulty increases greatly and therefore only little accurate data are available. Usually manometric methods give the best results. Chemical methods can be applied only when the amount of oxygen is not too small and if it is possible to exclude secondary reactions during the solution of the glass. It is more practical to use a colored oxide, like manganese or iron, as a reference standard, and from their relative effects determine just what is the distribution of oxygen between such colorless oxides as those of arsenic.

Oxygen Balance in Glasses

The importance of the role of dissolved gases in fining and decolorization is well illustrated by the reactions of oxygen. With a pure soda-lime glass there is no substance present which can retain oxygen. But with the introduction of fining agents, of coloring oxides, and of lead and barium, glass melts can take on as well as give off oxygen, and the complexity of the melting reactions is greatly increased. We speak of an "oxygen pressure" within the glass, the magnitude of which depends upon the composition of the base glass and the temperature.

The effect of fining agents may be based on physical or chemical actions. Agents with a purely physical action are salts with relatively high vapor pressures at glass melting temperatures. Sodium chloride and ammonium salts, for instance, affect the fining by their escaping to

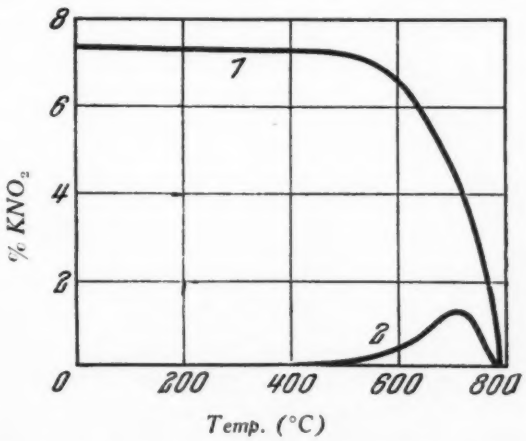


Fig. 1. Behavior of saltpeter in a glass melt. Curve 1: Decrease of nitrate content. Curve 2: Intermediate formation of nitrite.

form bubbles which have a stirring action, thus homogeneizing the glass. Other agents produce chemical reactions which are mainly connected with the splitting off of oxygen. A more detailed description of the effect on fining will be given later.

In the same way we add similar reagents for decolorizing purposes. The decolorization of glass consists of two separated phenomena. The first involves an oxidation of the ferrous oxide to ferric. The second step is an additional coloring of the glass so that grey, neutral tints are obtained. The first step makes it necessary that oxygen is available, and therefore agents are used which give off oxygen at temperatures above 1000°C. In the following paragraphs the main oxygen producing agents will be discussed.

SALTPETER. The addition of a small amount of alkali in the form of saltpeter is a general custom exercised in glass practice. Its effect is to oxidize organic impurities and to stimulate a general oxidizing atmosphere during the first stages of the melting process. We know by experience that saltpeter alone has no noticeable fining effects, nor does its addition change the iron oxide equilibrium to any remarkable degree. The reason is that this compound decomposes at relatively low temperatures to form nitrites. In the presence of silica nitrite reacts readily, and at about 1000°C. no traces of these compounds of oxygen can be detected in the glass batch.

Fig. 1 charts the behavior of saltpeter in a batch of normal soda-lime glass. Curve 1 indicates the decrease in nitrate, whereas Curve 2 with its pronounced maximum gives evidence of the formation and later decomposition of potassium nitrite. The results were obtained by heating samples of the glass batch containing potassium nitrate to different temperatures and determining analytically their content in nitrate and nitrite ion respectively. These and the following results are taken from a recent paper, "The Behavior of Oxygen Producers during the Melting and Fining Process of Glass," by C. Kuhl, H. Rudow, and W. Weyl. In the paper the analytical methods are extensively described. The experiments show that nitrates may give off oxygen and act as oxidizing agents up to about 800°C.

Saltpeter is mentioned here as a representative of a group of oxidizing agents which behave in almost the same way. Other nitrates behave similarly, and chlorates correspond to these quite closely. Potassium chlorate, for instance, when heated first forms perchlorate and later decomposes. We are sure that above 1000°C. no more oxygen will be evolved by it into the melt. This group of agents may be useful for oxidizing organic impurities, preventing formation of metallic lead in lead glasses, and oxidizing to ferric any iron compounds, such as ilmenite, $FeO:TiO_2$, which may be present.

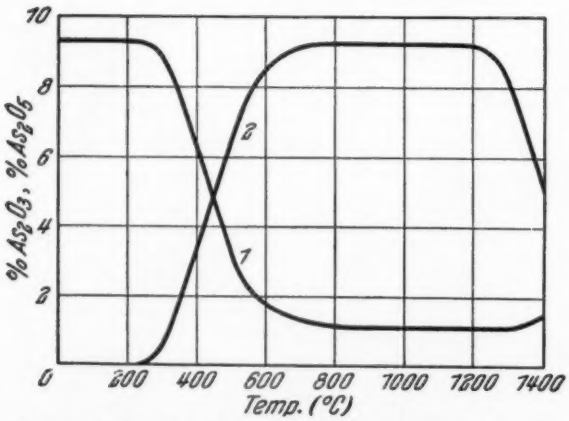


Fig. 2. Behavior of arsenic in a glass melt. Curve 1: Amount of As_2O_3. Curve 2: Amount of As_2O_5.

ARSENIC AND ANTIMONY OXIDES. At about 1000°C., where the reactions of the above group have been completed, only a small part of the silica has yet combined with the carbonates of the glass batch, and carbon dioxide evolution is still going on. This creates an atmosphere with a partial pressure of oxygen equal to zero, and favors the decomposition of Fe_2O_3 with increasing temperature. Therefore it is necessary to add other reagents which take a part of the nitrate oxygen and store it to higher temperatures. Arsenic and antimony compounds are most widely used for this purpose because other possibilities such as manganese, chromium, and vanadium are limited in their application by their coloring effects.

What is the effect of arsenic in the glass batch? According to the findings of G. Reissaus, arsenic itself can not be oxidized directly except in the presence of basic oxides or carbonates. The simple reaction $As_2O_3 + O_2 = As_2O_5$ will not take place. As_2O_5, decomposes if rapidly heated into metallic arsenic and As_2O_3, and the former may react with the oxygen present to again form As_2O_3. In the presence of carbonates or basic oxides, however, a complete oxidation of arsenites to arsenates can be obtained.

In the glass batch we have the conditions for oxidation of As_2O_3 by the saltpeter, so that in the first stage of the melting process arsenates are formed. These arsenates are rather stable and decompose only around 1400°C. with the evolution of oxygen. Fig. 2 shows the reactions of arsenic in a batch of soda-lime glass. Curve 1 indicates that above 200°C. the amount of As_2O_3 decreases, whereas Curve 2 shows the formation of As_2O_5 in the same temperature range. Between 800° and 1200°C. the greater amount of the arsenic is present in the form of As_2O_5. At about 1300°C. a considerable decrease in As_2O_5 can be observed, while the As_2O_3 content increases only slightly. The reason for this phenomenon is that As_2O_5 decomposes to form oxygen and As_2O_3, and the latter having a considerable vapor pressure escapes from the melt. The results have been obtained by careful analytical control of the glass batch heated to different temperatures and are in full agreement with earlier observations of W. E. S. Turner and of R. L. Frink, who found As_2O_3 crystals in bubbles.

It was of fundamental interest to study the reversibility of these reactions. For this purpose analyzed glasses containing As_2O_3 have been treated under an oxygen atmosphere for several hours, and it has been proved by manometric measurements that these glasses do react with the oxygen. The reversibility of this reaction opens the possibility that small oxygen bubbles may be redissolved by the glass melt at lower temperatures. This is in contrast to the non-reversible reactions of nitrates and chlorates and has to be considered in the choice of oxidizing agents for special low-melting glasses.

Antimony compounds behave similarly in many respects, and Fig. 3 shows the reactions of Sb_2O_3 in a glass

batch. Curve 1 indicates the oxidation of Sb_2O_3, starting at about 400° C., whereas Curve 2 shows the formation of Sb_2O_5 starting at the same temperature and being completed at about 1000°C. Furthermore, Curve 2 shows the decomposition of Sb_2O_5 at temperatures above 1200°C.

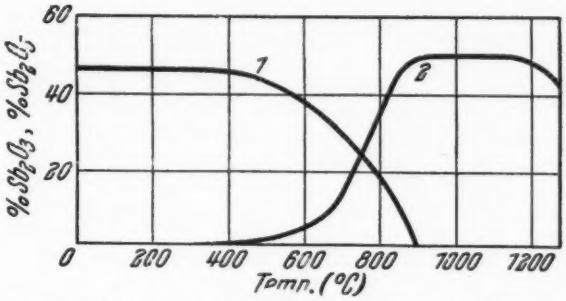


Fig. 3. Behavior of antimony in a glass melt. Curve 1: Amount of Sb_2O_3. Curve 2: Amount of Sb_2O_5.

The Mechanism of Fining

The effect of the oxygen evolution on the fining of molten glass has been studied and explained by Gehlhoff and his collaborators. Their explanation merits extensive quotation:

> When carbon dioxide is liberated into the melt, its partial pressure increases rapidly, so that the melt becomes supersaturated with gas. This gas has to be liberated where its partial pressure is smaller than in the melt. That means into the furnace atmosphere, into deeper layers of the melt, or into those bubbles and seeds which are present or nascent. The partial pressures of the gases in the seeds have to be smaller than that in the melt, for the melt is supersaturated and the pressure of the gases reaches values higher than in the surrounding atmosphere. In the bubbles, however, the gas pressure cannot be higher than the atmospheric pressure plus the pressure of the liquid above it. Consequently, the gas bubble exerts a sucking action on the surrounding melt. The more kinds of gas present in the bubble, the lower has to be the partial pressure of each single gas, and the stronger therefore the sucking and fining action. If several kinds of gases are present in the melt, they are liberated more readily, for the sum of the partial pressures easily reaches the value necessary for liberation. After the primary evolution of the largest amount of carbon dioxide, we may explain the effects of the fining agents as follows. We have different gases in each bubble. The partial pressure of the carbon dioxide has been decreased. On increasing the amount of fining agent, we certainly find a decreasing of the carbon dioxide content with time, and a relative increase of the gas liberated by the fining agents. When the pressures of both gases are approximately the same, we have the best conditions for fining. Increasing the amount of fining agent, therefore, will lead to an optimum amount, which is in agreement with experience.
>
> If we use oxygen for fining purposes (addition of saltpeter), it is possible to establish conditions where the last residue may be absorbed by the melt. To attain that we have to add compounds which are able to react with oxygen in a later stage of the melting process, for example iron or arsenic.

From the viewpoint of fining we are interested in materials which keep the oxygen up to high temperatures, and make it available during the fining interval. Besides this property we expect that a good fining agent is able to react with the excess of oxygen present in the form of small seeds. The same behavior is desired for the decolorizing of glass, especially for the oxidation of FeO.

Oxygen Balance in Barium and Lead Glasses

Besides arsenic and antimony, other compounds used in glass, such as lead oxide and barium oxide, are also able to store oxygen. This we know from analytical investigations of the gases given off by optical glasses high in these two oxides. It was found by Washburn, Footitt, and Bunting as well as by the later thorough work of Salmang and Becker that glasses containing As_2O_3, BaO, or PbO may give off remarkable amounts of oxygen if heated in a vacuum (see Table I).

Ordinarily the amount of available oxygen is so small that it is very difficult to determine it by chemical means. The situation is remarkably improved by the expedient of increasing the partial pressure of the oxygen from the normal one-fifth of an atmosphere to about three hundred atmospheres.[1] This shifts the equilibrium to the side of the higher oxide, so that the amount of oxygen which is available in barium and lead glasses can be determined with sufficient accuracy.

The analytical method is as follows: The glass is dissolved in a mixture of hydrofluoric and hydrochloric acids. Potassium iodide is added and reacts with any higher oxides which are present, liberating iodine. From the amount of free iodine, as determined by the disappearance of the starch-iodine blue on titration with standard sodium thiosulphate solution, the amount of peroxide, BaO_2, can be calculated.

A barium glass of the composition K_2O:BaO:$4SiO_2$ (31.4 per cent BaO) molten under an oxygen pressure of 300 atmospheres contained about 8 per cent BaO_2. Similar experiments with lead glasses prove that these utilize the available oxygen to form alkali plumbates. A lead metasilicate glass is not able to maintain available oxygen. Such a glass molten under 300 atmospheres of oxygen pressure does not give off oxygen in vacuum melting, nor does it give the iodine-starch reaction. If we add alkali to this glass, a higher lead oxide can be made stable in the form of alkali plumbate, K_4PbO_4. Now oxygen is given off in vacuum melting and an intensive iodine—starch reaction is obtained.

These experiments help to explain the behavior of barium and lead in glasses and make it possible to trace the available oxygen to the compound in which it is present. For example, the formation of BaO_2 in glass offers an explanation of the experiments of L. Springer on substitutes for arsenic-niter mixtures as decolorizing and fining agents. He found that potassium chlorate alone does not give good results, but in combination with barium compounds it has a definitely useful effect on the iron oxide equilibrium.

Our explanation is the potassium chlorate alone decomposes at fairly low temperatures, and therefore cannot affect the ferrous-ferric equilibrium. In the presence of barium the oxygen which the chlorate evolves

[1] H. Möttig and W. Weyl.

TABLE I. Gas Content of Various Glasses

(A) Washburn, Footitt, and Bunting's Analyses

Glass Type	Volume per cent at Standard Temp. and Pressure				Weight, per cent			
	O_2	CO_2	N_2	Total	O_2	CO_2	N_2	Total
Barium flint 1	83	27	1	110	0.035	0.011	—	0.046
Barium flint 2	36	12	1	48	0.015	0.0045	—	0.020
Light flint	4.5	10	3	18	0.045	0.014	0.0025	0.021
Borosilicate	6	5	6	17	0.0036	0.0035	0.0031	0.010

(B) Average Values Taken from Salmang and Becker

Glass Type	Volume of Gas in cc.					Based on Sample of
	O_2	CO_2	SO_2	H_2O	Total	
Holloware	0.07	0.5	—	2.5*	0.8	10 gm.
Carbonate	0.38	0.6	—	5.0	1.5	10 gm.
Sulphate	3.5	0.8	7.0	—	12.4	5 gm.
Barium borosilicate	14.2	22.7	—	4.3	37.5	10 gm.
Barium crown	4.6	1.1	—	6.1	7.1	20 gm.
Extra dense flint	4.0	0.4	—	5.0	4.5	30 gm.
Dense flint	1.1	0.4	—	3.9	1.6	30 gm.
Dense flint plus 3% CeO_2	3.8	0.6	—	6.3	4.5	30 gm.

*Corresponds to 0.02 per cent by weight.

(C) Analyses by Dalton

Glass Type	% Composition of Gases from 1 gm. Sample				Vol. of Gas in cc.
	O_2	CO_2	SO_2	H_2O	
Barium (optical)	41	37	—	22	0.71
Soda-lime (milk bottle)	11	3	34	51	0.93
Borosilicate (heat resistant)	3.5	4.5	—	92	0.40
Soda-lime (bulb)	13	7	36	44	0.90
Borosilicate (heat resistant)	7	4	0.3	89	0.36
Borosilicate (bulb)	3.5	3	2.5	94	0.74
Lead (sign-tubing)	54	7	8	39	0.70
Soda-lime (experimental)	64	8	10	28	1.41
Borosilicate (heat resisting)	3	4	2	93	0.44

(D) Average Values for Volumes of Gases Found by Hahner, Voigt, and Finn

Glass Type	Gas per 100 g. of Glass in ml.		
	O_2 + Res.	$CO_2 + SO_2$	H_2O
Borosilicate crown A	0.2	0.1	49
Borosilicate crown B	0	0	29
Light barium crown A	1.0	0	20
Light barium crown B	1.2	0.7	21
Light barium crown C	1.1	0.1	17
Light crown A	1.7	4.0	33
Light crown B	5.4	4.1	38
Window glass A	10.2	43.1	16
Window glass B	17.1	17.0	23
Window glass C	32.5	26.6	22
Window glass D	22.2	51.2	26
Window glass E	7.9	40.2	32
Window glass F	3.3	40.4	26
Soda-lime tubing	3.0	14.0	23

leads to barium peroxide which is rather stable in comparison with chlorate. It decomposes at a later stage in the melting, and the oxygen can then react with the FeO in the glass.

Oxygen from Saltcake

A similar evolution of oxygen is obtained from glass batches containing sodium sulphate as a fining agent. Sodium sulphate decomposes giving off SO_2 and oxygen according to the equations:

$$Na_2SO_4 \rightleftarrows Na_2O + SO_3$$
$$2SO_3 \rightleftarrows 2SO_2 + O_2$$

This decomposition offers the advantage that we have two different gases in the bubble and that such a gas mixture has a good fining action. Using sodium sulphate as a source of alkali makes it necessary to work under strong reducing conditions, sometimes even requiring addition of carbon to the batch. Here, of course, the effect of the oxygen will be over-balanced by the reducing conditions during melting.

An extensive study on the role of sodium sulphate on the reactions of glass-melting, especially on the color of iron-containing glass has been published by Jebsen-Marwedel and Becker.

Oxidation-Reduction Equilibria

Observations on the effect of oxygen pressure on the equilibria among the various valence states of coloring oxides have a double usefulness. For they can be used as indicators of the distribution of the oxygen, and they can also be used to explain some of the puzzling coloring effects obtained with variations in furnace atmosphere or other melting conditions.

Coloring oxides in their highest state of valency have a certain oxygen pressure which is so great that the equilibrium is always displaced toward the lower oxide. The decomposition pressure of the individual coloring oxides when dissolved in a glass around the melting temperature of the glass forms a measure for their stability. It is not dependent on the temperature alone, but also on the bonding condition of the separate oxides, which is in turn a function of the glass composition.

An interesting problem in the chemical constitution of glass deals with the question how a certain amount of available oxygen may be distributed among different oxides of low valence. Suppose we have a glass containing arsenic and manganese, both in their state of lower valency—As_2O_3 and MnO—and a change in the furnace atmosphere offers the possibility of an oxidation. Which of the two is oxidized first, or how is the oxygen distributed between arsenic and manganese? Two factors are definitely involved: the reaction speed and the equilibrium. The reaction speed depends upon the temperature and the viscosity of the glass. In other words, on the diffusion speed of the higher oxide. The equilibrium depends mainly upon temperature and the composition of the base glass. If one oxide, by its oxidation, increases very much in its acidity, whereas another oxide does not, basic glass composition must certainly favor the oxidation of the first.

The same question differently expressed is "When do two oxides give rise to a chemical reaction in the glass?" We know for instance that Mn_2O_3 in a certain glass oxidizes the FeO present. As_2O_5 behaves in the same way. We call manganese oxide and arsenates oxidizing agents, but we have to bear in mind that they act as oxidizing agents only with respect to iron oxide. Arsenic may react as a reducing agent in other glasses for we know that As_2O_3 reacts with CrO_3 and Mn_2O_3 leading to As_2O_5 and Cr_2O_3 and MnO respectively. In a systematic investigation on the behavior of different oxides, C. Kühl, H. Rudow and W. Weyl came to the conclusion that the following series explains many possible reactions:

$$CrO_3 — Cr_2O_3$$
$$Mn_2O_3 — MnO$$
$$CeO_2 — Ce_2O_3$$
$$As_2O_5 — As_2O_3$$
$$Sb_2O_5 — Sb_2O_3$$
$$Fe_2O_3 — FeO$$

From this sequence it can be predicted how the available oxygen will be distributed in a normal soda-lime glass containing small amounts of the above-mentioned oxides in their lower state of valency. First, FeO would

(*Continued on page* 266)

MODERNIZATION OF THE STERLING GLASS PLANT

The problem was to set up an up-to-date glass plant in an outmoded structure, yet in such a way that the outer shell can be removed later and replaced with modern factory buildings.

Late last year The Warfield Co., Chicago, instituted an extensive reconstruction and betterment program at its Sterling Glass Division plant, Lapel, Ind., and the reconditioned factory was placed in production recently. The Sterling plant is now an excellent example of what can be done to adapt up-to-date equipment and methods for use in an old structure at a reasonable cost and the improved operating results reflect the care and forethought that went into the betterment plans.

The foremost requirement at Sterling was a new tank. It was necessary to place the design and construction of the new furnace in the hands of an outside firm and the Forter-Teichmann Co. was engaged to engineer the complete reconstruction program, as well as the design and construction of the new tank. Plans were completed and work was started shortly after the first of the year, practically all of the plant personnel being continued in employment on the revamping job.

Since the construction of a new building had to be postponed to a later date and was not included in the present program, the design and location of the tank to conform to the limitations of the present structure presented many difficulties. The building is of wooden mill-type construction and the greatest difficulty was to get sufficient height from the forming machine floor to the metal line. Although a distance of 12 feet would be most desirable, it was found impossible to raise the glass level more than ten feet above the factory floor, even with the crown of the furnace close to the bottom chords of the roof trusses.

With the construction of a new building at a later date in mind, the problem of securing the preferable 12-foot height with the present tank in the new building was solved in a very ingenious way. The steelwork and structural binding of the Sterling furnace has been so designed and built that the whole tank can be jacked up two feet bodily when the height limitations of the old building are removed.

New Melting Tank

The new furnace is of conventional regenerative design with three ports on each side of the melting end, which is 16 ft. wide and 24 ft. long inside. A bridge wall with a 12 by 24 in. throat separates the melting end from the refining end, the front wall of the tank being swung on an 8½-ft. radius from a point 2 ft. in front of the bridge wall. There are openings for four feeders in the front wall of the tank and the glass depth in both melting and refining ends is 3 ft. As stated above, the metal line is 10 ft. above the factory floor in front of the tank.

Since the new tank is more or less crowded into the old building, it is difficult to show a good view of the complete furnace, but Fig. 1 gives a general idea of its proportions. This view shows the feeding end and the doghouse can be seen at the center of the rear wall. One of the brick piers that support the left side of the furnace can be seen below the charging platform, with the gas and air checkers further to the left. The reversing valves are located in the space beneath the charging platform and are operated by winches on the platform. In the picture the crown is obscured by the batch buckets on the monorail, but it rises to within a few feet of the bottom chord of the roof truss. The producer gas line can be seen entering from the right below the platform.

The melting capacity of the new tank is from 45 to 50 tons per day, the furnace being charged with batch every 20 minutes and reversed every half hour. The temperature recording instruments are mounted on the charging floor within easy sight of the operator. The blocks for the bottom and side walls were furnished by Pittsburgh Plate Glass Co., Corhart blocks being used in the throat. Harbison-Walker and Hawes silica brick were installed and the checker brick came from the Davis Fire Brick Co. North American Refractories Co. and Harbison-Walker Refractories Co. supplied the first quality fire brick, other fire brick being furnished by the Union Mining Co. Bethlehem Steel Co. provided the steelwork for the furnace.

The tank is located on the building center line, which runs east and west, the front of the tank facing toward the west. The forming machines are located in the space between the front of the tank and the building wall, the two machines at the northwest corner being shown in Fig. 2. The ware is conveyed to four 80-ft. Amsler-Morton lehrs, two of which are located along each side of the furnace. The annealed ware is discharged near the melting end of the tank and is inspected and packed at this point.

Feeder Improvements

One Lynch type IR and three type LA machines are used to fabricate the ware and are served by Miller feeders which were in use on the old tank and have been

Fig. 1. View of the rear of the new melting tank at the Sterling Glass Division, The Warfield Co., Lapel, Indiana, showing batch buckets, doghouse and charging platform.

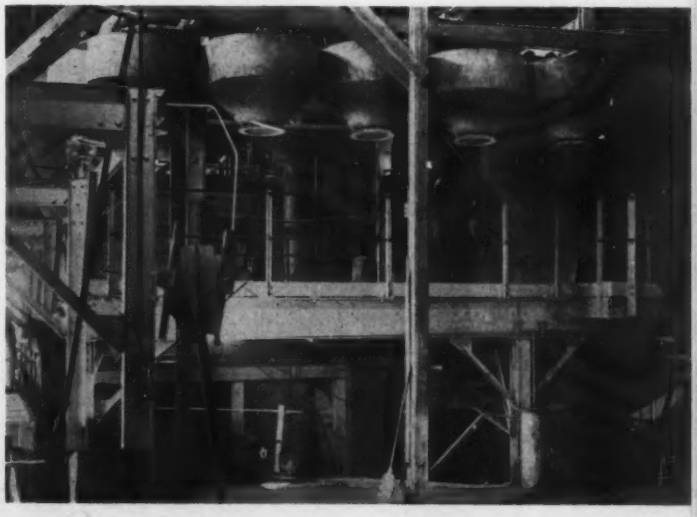


Fig. 2. Two of the Miller feeders and Lynch forming machines. Note the blown ware passing to the lehr on the conveyor.

adapted for the new installation by changing the controls, etc. The forehearths for the two center feeders were changed over to standard Hartford-Empire design and their length was increased to ten feet from a former length of three feet. Feeders No. 1 and No. 4 were also lengthened about six inches to suit the location of the lehrs. Findlay refractories were used in the channels. The feeder forehearths are fired with oil, Hartford-Empire burners being used. These changes in the feeders and forehearths have produced much greater uniformity in operating conditions.

The cooling system for the tank was designed by Forter-Teichmann, cooling air being supplied by a No. 4 American Blower Co. fan housed in a small structure at the south side of the building. The fan is driven by a 20-hp. G-E motor. The cooling air piping was furnished by C. F. Strasmer, of Anderson, Ind.

Cullet Equipment

The producer house is located to the north of the main building and the cullet equipment is located in the space between the two structures. A rectangular steel bin, formerly used for storage of mixed batch at the furnace, was moved to the new location for cullet storage and the old elevator was lengthened to take crushed cullet at about ground level and discharge it into the bin. A No. 2½ Wheeling cullet crusher was furnished by the Continental Roll & Steel Foundry Co. and is driven by a 15-hp. Allis Chalmers motor. Cullet is brought to the crusher by a belt conveyor from a point near the machine end of the main building. At present the conveyor is loaded by hand. The discharge pipe from the cullet storage bin leads directly into the batch mixing house.

The batch house is located adjacent to the north side of the main building and at the east end of the open space in which the cullet handling equipment, mentioned above, is placed. Raw materials are unloaded from cars and placed in bins on the floor level below, this level being nearly 4 ft. below the adjacent floor of the main building and a little over 11 ft. below the metal line in the tank. On this floor the batch ingredients are collected in wheelbarrows, weighed on a platform scale and dumped into a hopper at the side of the scale. From the hopper the materials pass into a bucket elevator which discharges into the mixer.

Since the mixer had to be raised nearly five feet to permit it to dump directly into the batch buckets at the monorail level, a new steel framework for the elevator and mixer was constructed. The drives were also changed to individual motor drives, power being transmitted through Allis Chalmers V-belts. Power for the elevator is supplied by a U. S. totally-enclosed 1-hp. motor and a 5-hp. General Electric motor drives the Simpson mixer.

Up-to-Date Prepared Batch Handling

The equipment for handling the mixed batch from mixer to tank is quite out of the ordinary for a plant of this size, since it incorporates the use of unit batch buckets on a monorail system. The installation is of particular interest, because the designers had to overcome what are considered the main obstacles to the installation of such a system in an existing plant. These are lack of support for the monorail in the building structure itself and a difference in level between the mixer and the charging point of the furnace. In this case the use of an auxiliary elevator and the inherent adaptability of the monorail, together with a suitable structural steel support, provided the answer to the problem and the Sterling plant now has the advantage of the most up-to-date

Fig. 3. Buckets filled with prepared batch on the monorail near the opening into the batch house. The framework by which the monorail load is carried to the building columns can be seen.

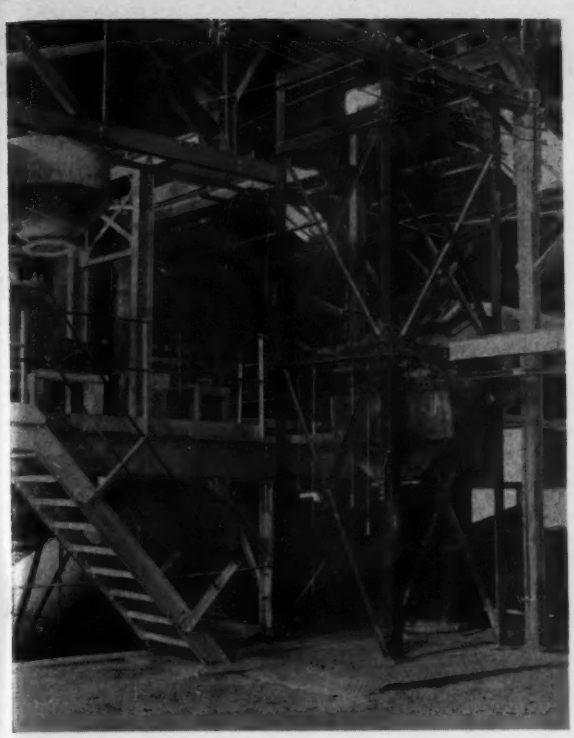


Fig. 4. The elevator which raises the batch buckets to the charging level. The incoming gas main from the producer house can be seen directly behind the elevator framework.

method for the prevention of batch segregation and the amelioration of dusty conditions in the operating room.

From beneath the mixer the monorail enters the main building from the batch house, as shown in Fig. 3, and passes to within about ten feet of the building center line, at which point it makes a right-angle turn toward the rear of the tank. As can be seen, this section has a side track with suitable switches for the storage of empty batch buckets near the mixer. The buckets shown in the illustration are filled with batch.

Mixed Batch Elevator

The monorail proceeds toward the rear of the tank, as illustrated on the front cover of this issue of THE GLASS INDUSTRY, and reaches the auxiliary elevator at the edge of the charging platform. The bottom of the elevator structure with the tank operator at the lower control buttons can also be seen in this illustration. The entire elevator structure is shown in Fig. 4. An electric hoist is located in the top of the structure and raises or lowers a carriage which incorporates a movable section of monorail. The operation of the hoist is controlled by push-button stations at both charging platform and ground floor levels.

At the point of entrance to the elevator the bottom of the monorail is about a foot below the metal line. The elevator has a lift of a little over seven feet, so the bottom of the monorail at the upper level is about 6¼ feet above the metal line and the batch can be discharged from the bucket to the doghouse by gravity. The monorail makes a loop above the charging platform, thus providing plenty of storage space for mixed batch near the furnace.

Fig. 5 illustrates the furnace charging operation. A swinging chute is brought into position over the doghouse and the batch is released from the bucket through a sliding gate. When a convenient amount has been placed in the doghouse the chute is swung out of the way and the charge is pushed into the furnace with a hoe. Twenty buckets are included in the system, each having a capacity of 2,000 lb. The monorail, buckets, carriers, elevator, etc., were furnished by the American Monorail Co. through R. P. Mahaffey, of Pittsburgh, who was selected as contractor on the batch handling system.

The betterment program in the power house at the Sterling plant includes new and larger equipment for power generation, water softening and compressed air. An 80-kw. generator was replaced by a new 225-kw. machine furnished by the Rockford Power Machinery Co., the new generator furnishing ample power for the new

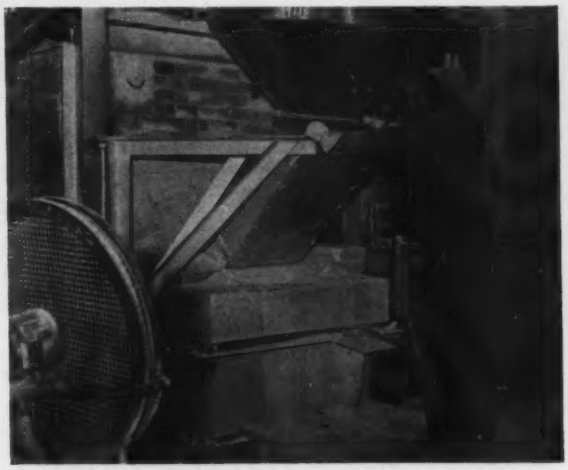


Fig. 5. Furnace charging procedure, showing the use of the swinging chute above the doghouse.

Fig. 6. Part of the operating staff at Sterling Glass. Left to right: Chas. Breese, Shipping Dept.; Ward Shetterly, Production; John Patrick, Fact. Mgr.; Frank Bolton, Fact. Mgr.; W. J. Mathews, Supt. Other staff members not present: Wm. Taylor, Fact. Mgr.; Shirley Stanford, Master Mech.; Jack Galliher, Engineer, and Wilson Edwards, Mould Shop Foreman.

individual motor drives with capacity for other projected motorized drives in the future. Boiler room difficulties resulting from the very hard water available have been eliminated by the installation of an Elgin Zeolite water softener. The air compressor improvement is not yet complete, but two Worthington, motor-driven, feather-valve compressors, purchased some time ago, will shortly replace a duplex, steam-driven compressor now in use.

The products manufactured by the Sterling Glass Division include packers and liquor ware, about 30 per cent of the total production being used by the Warfield Co. for packaging its own food products. Throughout the reconstruction and improvement campaign the plant has been under the direct supervision of W. J. Mathews, an experienced operating man well-known in the industry. Fig. 6 shows Mr. Mathews and some of the members of the operating staff in one of their few off moments. The completion of this phase of the improvement program at Sterling Glass reflects great credit on the owners, engineers and operators and indicates the trend toward better production facilities in American glass plants, both large and small.

PRODUCTION FIGURES FOR THE GLASS INDUSTRY DURING MAY

Glass Containers: Production of glass containers during the month of May was 3,836,956 gross, bringing the 1938 total to 17,230,686 gross. Shipments during May were 3,902,002 gross and 17,039,733 gross for the first five months of 1938.

Plate Glass—The total production of polished plate glass by member companies of the Plate Glass Manufacturers of America in May, 1938, was 3,866,052 sq. ft., as compared to 3,819,735 sq. ft. produced by the same companies in the preceding month, April, and 19,437,246 sq. ft. produced in the corresponding month last year, May, 1937.

Window Glass—Window glass production during May, 1938, was 360,256 boxes, which represents 22.2 per cent of industry capacity. As compared with this, May, 1937, production was 1,293,483 boxes which represented 79.7 per cent of industry capacity.

BRIQUETTING OF GLASS BATCH

In the summary of the paper, "Briquetting of Glass Batch," presented before the Urbana Conference on Glass Problems by F. G. Schwalbe of the Toledo Engineering Co., there was a typographical error. On page 225 of the June issue of THE GLASS INDUSTRY, in the second tabulation, column one, the total of the investment for cullet-free briquettes is given as $.0226. This is incorrect; it should read $.0266.

SILVERMAN RETURNS FROM EUROPE

Dr. Alexander Silverman, head of the Department of Chemistry, University of Pittsburgh, has recently returned from Europe, where he was a delegate to the Tenth International Congress of Chemistry from the United States government and the American Ceramic Society. At these sessions which were held in Rome, May 14-21, Dr. Silverman presented a paper entitled "Some New Developments in American Glass Manufacture." He also served as a councilor representing the National Research Council and the National Academy of Sciences for the Thirteenth Conference of the International Union of Chemistry which is the standards body of the world in this field.

Following the Congress, Dr. Silverman went to Naples and then to Paris where he presented a certificate of honorary membership in the American Ceramic Society to Andre Delloye for his father, who was too ill to receive visitors. The presentation was made in Director Gentil's office at the Saint Gobain Glass Works.

Dr. Silverman also was fortunate enough during his Paris visit to secure some unusual specimens of Navarre and Dorchemont for his collection; also, some old specimens of Daum, a specimen of St. Louis, and one of the new diamond point decorations of Moser of Czechoslovakia.

M. I. T. GLASS MEETING, JULY 11-23

A special summer program on ceramics will be presented by the Department of Metallurgy of the Massachusetts Institute of Technology during the two weeks of July 11-23. The program is divided into two groups: (1) to the nature of glass, beginning the week of July 11, and (2) to the reactions in ceramic materials on heating, beginning the week of July 28. Many interesting papers and discussions have been planned and, since only a limited number can be accommodated, it is suggested that applications for attendance be mailed to F. H. Norton, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass., immediately. The tuition fee for each of the programs will be $30.

BLACKBOARDS MAY BE WHITE GLASS

The New York City public schools, according to Ellsworth B. Buck, chairman of the school board's building committee, are experimenting with the idea of replacing the old-fashioned blackboard with a white "board" and black chalk. The new type wall panel will be constructed of glass with a white surface. As a matter of fact, the use of glass for blackboards is not new. For the past year a black glass surface instead of the traditional slate has been tried in Public School No. 59, on the theory that glass presents a more finished surface than slate.

In so far as the most recent experiment is concerned, Hunter College has gone the school board one better. and has been experimenting with a yellow panel and black chalk, a color combination recommended by lighting engineers.

HONORED AT OHIO STATE

Dr. Robert E. Sosman of the research laboratories of the United States Steel Corporation and retiring president of the American Ceramic Society was awarded the honorary degree of Doctor of Science at Ohio State University. He received a professional degree last year. Harold E. Simpson of the Mellon Institute also received an honorary degree. His thesis was "The Effect of Chemical Composition on the Durability of Bottle Glass."

• Announcement has been made of the appointment of Harold W. Wilson as manager of the Montreal branch of Hobbs Glass Limited of London, Ont. Mr. Wilson has been in charge of the company's new Notre Dame St. plant.

METALLURGICAL ANALYSIS OF GLASS MOLD CAST IRONS: I

By J. S. VANICK
International Nickel Co., Inc.

• *This, the first of two articles on the use of nickel alloys for mold castings, deals with machinability, fine finish, density and close-grainness, prevention of sticking, resistance to heat checking and resistance to surface deterioration. In his second article, to appear in the August issue of* THE GLASS INDUSTRY, *Mr. Vanick will discuss low thermal expansion, high thermal conductivity, growth and scaling, and resistance to wear, corrosion and staining of molds. He will also treat the means of grading and selecting cast irons for molds, together with performance data and production.—The Editor.*

Foundrymen manufacturing mold castings have endeavored for years to meet the exacting conditions of glass mold service. The plain iron base compositions and mixtures have varied up and down in carbon and silicon contents . . . often deliberately out of balance in the attempt to achieve improvements.

Foundrymen and metallurgists have applied the common and rare alloying elements in various amounts in the hope of arriving at some composition that would meet all conditions. It is doubtful whether a single composition can meet all conditions, but it is evident that high carbon irons possess valuable characteristics, while low carbon irons of the high strength type suffer handicaps that prevent their general acceptance. Thus a cast iron possessing a tensile strength of 50,000 or 60,000 p.s.i. is of less interest to a glass shop than one possessing a strength of 20,000 p.s.i. As a matter of fact, if the strength at any time could be used as an index, an iron that is weaker still than the 20,000 p.s.i. product, might become a useful glass mold. Tables I and II summarize typical glass mold compositions.

During the experimental programs, glass molds moved from the chill cast type of casting into progressively stronger and harder sand cast types, and at this time, have completed the cycle, returning again to popularity the soft, chill-densened, mold casting. In addition to being inexpensive the essential requirements of mold irons are listed in the following sections:

I. Glass molds whether of the press or blow types must possess ability to be rapidly machined to a high finish.

II. A structure conducive to the formation of a fine-grained, surface-finish.

III. Density or close-grain throughout.

IV. A graphite particle population in the surface fine enough to prevent sticking.

V. Resistance to heat checking, leading to the prevention of sticking.

VI. A resistance to deterioration by heat, avoiding a fogging of the ware and requiring re-dressing.

VII. A low thermal expansion.

VIII. A high thermal conductivity.

IX. Resistance to growth and scaling.

X. Resistance to wear, corrosion, contamination and staining.

I. Machinability: The outstanding requirement in a glass mold cast is its ability to be machined rapidly and easily to a high finish. Freedom from slag, pits, blows and porous spots is essential. Consequently, chill cast, soft, fluid, close-grained, dense, irons are in demand. Such irons appear in A and Nos. 1, 2, 4 and 5 of the chill cast series and 10 of the sand cast series of Tables I and II. Remaining types are moderately harder and stiffer enough to retard shop production which may cost $40.00 to $200.00 on a mold worth $4.00 to $8.00 as a casting.

II. Fine Finish: Structures likely to form a fine-grained surface finish must be made from compositions susceptible to such finish. Chill casting is positive, perhaps violent, in shortening the crystallization interval and consequently chill cast irons must of necessity be fine-grained. The greater the obstruction to grain growth,

Presented at the Fifth Conference on Glass Problems at the University of Illinois, Urbana, Ill., May, 1938.

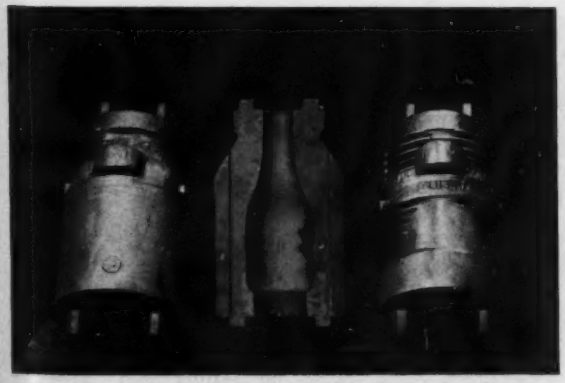
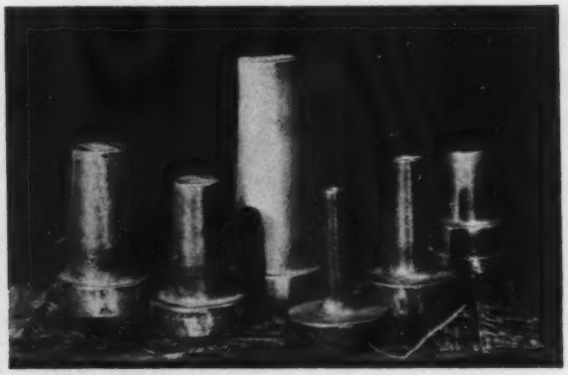


Illustration of half-sections of three milk bottle molds made of Iron No. 4—chill cast and annealed.



Group of plungers made of Iron No. 11, chill cast and annealed.

TABLE I. TYPICAL CHILL CAST MOLD COMPOSITIONS

High Carbon Type					Low Carbon Type	
	A				B	
TC	3.50				TC 3.10	
Si	2.30				Si 2.75	
Tensile	21,000				Tensile 28,000	
BHN	160				BHN 190	
			Alloy Cast Iron Types			
Type	1	2	3	4	5	6
TC	3.50	3.50	3.50	3.50	3.6-3.8	3.6-3.8
Si	2.30	2.30	2.00	2.00	1.4-1.6	1.4-1.6
Ni	0-15	.60	1.00-1.25	1.00-1.50	1.20-1.50	1.20-1.50
Cr	.30	.30	.30	None	—	None
Mo	None	None	None	None	None	**.20-.30
Cast	Chill	Chill	Chill	Chill	—	—
Annealed	Yes	Yes	Yes	Yes	Yes	Yes
*Tensile	22,000	24,000	28,000	26,000	32,000	35,000
*BHN	170	180	200	180	190	210

GRADING QUALITY OF GLASS MOLD IRONS

Physical Property No.	Maximum Grade Value	Chill Cast Series A	B	1	2	3	4	5	6
I. Machinability	200	180	120	140	160	120	180	200	140
II. Fine Grain	100	70	60	70	80	80	80	90	100
III. Density	100	70	60	80	80	80	80	90	100
IV. Graphitic	100	70	50	70	60	70	80	90	100
V. No Checking	100	60	40	50	50	60	70	90	100
VI. Heat Res.	50	40	30	30	35	35	40	50	50
VII. Low Exp.	100	50	60	70	80	80	70	90	100
VIII. Hi-Cond.	100	60	70	70	80	80	70	90	100
IX. Low Growth	100	50	40	60	70	80	70	80	100
X. Low Wear	50	25	30	30	40	50	30	35	45
	***1,000	675	560	670	735	735	770	905	935

*Before annealing. Test bar values.
**Vanadium .10% may be substituted.
***Highest number represents the best grade.

TABLE II. TYPICAL SAND CAST MOLD COMPOSITIONS

	C	D	E
TC	2.75	3.20	3.60
Si	2.00	2.10	2.30
Mn	0.60	0.50	0.50
*Tensile	50,000	33,000	20,000
BHN	250	190	160

	10	11	12	13	14
TC	3.70	3.10-3.40	3.10-3.40	3.00-3.20	2.70-2.90
Si	2.25	1.30-1.50	1.80-2.30	1.00-1.20	1.50-1.80
Mn	0.58	0.50-0.60	0.50-0.60	0.50-0.70	0.70-0.90
Ni	1.85	1.25-1.50	0-0.50	1.40-1.60	1.50-2.00
**Cr	None	0.30-0.60	0.20-0.30	0.20-0.30	None
**Mo			0.40-0.60		
Anneal	Yes	Yes	Yes	Yes	Yes
*BHN	174-184	220	210	220	220-240
*Tensile	24,000	38,000	35,000	40,000	55,000

GRADING QUALITY OF GLASS MOLD IRONS

Property No.	Maximum Grade Value	Sand Cast Series C	D	E	10	11	12	13	14
I. Machinability	200	80	120	180	200	140	120	140	120
II. Fine Grain	100	70	50	40	60	70	60	70	90
III. Density	100	90	70	50	60	90	80	90	100
IV. Graphitic	100	50	70	60	90	70	60	80	60
V. No checking	100	40	60	40	90	70	60	80	50
VI. Heat Res.	50	40	30	20	25	35	35	35	35
VII. Low Exp.	100	60	50	40	60	60	60	80	80
VIII. Hi-Cond.	100	60	50	40	40	70	60	80	60
IX. Low Growth	100	60	50	40	50	60	60	80	70
X. Low Wear	50	30	25	20	25	30	30	30	35
	*1,000	580	575	530	700	695	625	765	700

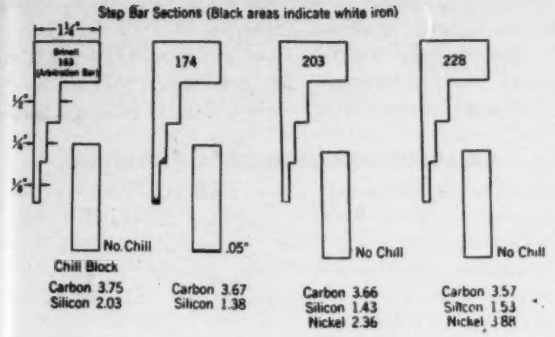
*Before annealing. Test bar values.
**Vanadium .10% may be substituted.
***Highest number represents best grade.

the finer the crystal pattern, provided no white iron or mottle forms. All of the chill cast irons and most of the sand cast ones possess this attribute. Sand casting irons numbered A, 1 and 4 of the chill cast group (Table I) is occasionally done for emergency purposes, usually with poor results. Silicon in excessive amounts promotes graphitization into relatively low temperature ranges upon solidification, and with high carbon contents open-grained irons are inevitable unless chill cast. Solidification in chill casting at the surface of the chill is a matter of a fraction of a second, yet mobile impurities, such as gas, sulfides, etc., may be propelled inwardly beyond the border of the chilled zone into the internal regions. The occurrence of a highly graphitic, fine-grained backing extending to the surface of the mold, is discussed.

III. Density and Close-Grainness throughout the body of the mold becomes a necessary attribute toward retarding mold deterioration by heat effects, such as thermal expansion, thermal conductivity, as well as the normal requirements of uniformity in properties, such as hardness and micro-structure. Most of the alloys contribute toward graphite refinement and in chill cast molds nickel, manganese and molybdenum should help as illustrated in Fig. 2 for irons similar to mold irons. Silicon promotes coarsening and a moderate reduction should help. Chill cast irons Nos. 1, 2, 4 and 5 (Table I) are typical. Sand cast irons (Table II) can be densened by reducing the carbon or silicon contents as in No. 13 or 11, or reducing both carbon and silicon as in B and 14. This is illustrated in Figs. 1 and 2 for irons similar to mold irons.

IV. Prevention of Sticking: A high graphite particle population seems to be essential. Here high carbon, fine-grained irons take the lead and A, 1, 2, 4 and 5 of the chill series (Table I), while 10 and 13 of the sand cast (Table II) series possess second best desirable properties. The remaining harder irons of the sand cast series may possess a very fine-grained structure but are more susceptible to cracking and an earlier occurrence of sticking. If carbide-stabilizing elements are present in excess, as illustrated in Fig. 3, sticking may occur due to the tendency for the hard particles of carbide to polish into relief and act as hooks upon which the soft glass will catch. Such carbides if present in the original casting will persist and remain unchanged throughout a relatively drastic anneal. The chill cast irons are less susceptible to this occurrence. The chilled surface in a slightly unbalanced composition might contain a small amount of chill or carbide in the skin which machining will remove. The absence of excessive amounts of carbide-stabilizing elements in the chill type cast irons would encourage destruction of any residual carbide during the ordinary anneal. Sticking is closely related to finishing (Section II) and heat checking (Section V). Irons 5 and 6 (Table I) after annealing, high in graphite content, machinable, soft, tough and fine-grained, will bear watching in any competitive test.

V. Resistance to Heat Checking: Requires irons possessing the qualities of Sections IV, VII and VIII, along with an inherent weakness and a low modulus or a high susceptibility to deform without rupturing. A high graphite particle population assists in preventing the propagation of microscopic ruptures into cracks. Under the repeated heating and cooling to which molds are subjected, microscopic fissures are bound to occur. Thermal expansion and contraction under the blistering heat of the glass gob or articles creates a stressed surface condition which finds relief by cracking. If the body is freely pierced by graphite particles a microscopic fissure travels from its source to a neighboring graphite particle, there dissipating its stress and stopping the propagation of the crack. A beach of sand grains or a bed of moist mud possessing low strength and poor coherence will not crack upon drying, but a coherent, partially dried mud, breaks up readily into "alligator cracks," characteristic microscopically of the heat checks in a mold surface.



No.	41	42	43	44	45
Tensile strength	21,000	22,000	22,000	32,000	34,000
Transverse	2,900	3,200	3,400	4,500	4,800
Nickel	....	....	....	2.36	1.10
Chromium	....	....	....	....	0.51
⅛-in. section fracture	gray	gray	Ce	gray	Ce
¼-in. section fracture	gray	gray	Ce	gray	gray
½-in. section fracture	gray	gray	gray	gray	gray
1¼-in. section fracture	gray	gray	gray	gray	gray
Chill on block	0	0	.05	0	.50
Carbon	3.50	3.70	3.70	3.70	3.70
Silicon	2.60	2.00	1.40	1.40	1.50

Ce—Chilled edge.

Fig. 1. Reducing silicon content from 2.60 to 1.40 per cent in high carbon irons begins to produce white, unmachinable surfaces underneath the chill, but with an improvement in density and strength. A nickel addition eliminates the white iron, restores machinability and builds up additional strength with grain refinement. A nickel-chromium addition to this iron deepens the thickness of the unmachinable chill cast zone as shown for No. 45, but if *sand cast* produces a good plunger type material. (See Figs. 2 and 3.)

The graphite particle population can only be increased by refining the size of the particles and also by increasing the quantity of graphite. An iron of the type of A (Table I) is carrying about all the graphite it can hold because of the limiting solubility of carbon in iron in the presence of silicon. Thus a silicon free iron-carbon alloy may contain up to 4.3 per cent carbon dissolved in the liquid solution. As silicon is added, the solubility for carbon is decreased about 1 per cent of carbon for 3 per cent of silicon as illustrated in Table IV.

It is evident that the usual chill cast composition containing 2.1 to 2.4 per cent silicon is carrying all the graphite it can hold. Since nickel does not disturb the relation appreciably it is possible to increase the graphite population by using a lesser silicon content as 1.5 per cent silicon, and maintaining this high carbon solubility, machinability, density with appropriate nickel additions. It is for this reason that irons No. 5 and 6 of Table I possess outstanding merit.

Local distortions in a mold, caused by the shape of the cavity, or unequal heating or cooling, or poorly fitted joints, all find relief in the low modulus, weak and densely graphite-populated type of iron. The presence of iron carbide, which occurs in the pearlite, if in appreciable quantity, is of no particular help, and since some must be present, a carbide toughening or carbide plate distributing element like molybdenum or vanadium should be helpful. Annealing, both for the purpose of dimensionally stabilizing the castings and further softening and diffusing their carbide contents, is helpful. It is preferably a high temperature one consisting of 1550° to 1650° F. heating and slow cooling. Alloy constituents remain in the ferrite or residue to assist in retarding subsequent deterioration by heat. Outstanding contestants for first place are irons Nos. 5, 4, 6 and with 2, 1 and A seconds (Table I) are among the chill cast group. Irons 10, 13, 11 and 12 follow for sand cast molds (Table II).

VI. Resistance to Surface Deterioration: Heat, as distinct from wear or corrosion, may produce surface defects. Molds operate like dies, shaping the glass at high temperatures but at relatively low pressures. Surface imperfections must not occur or scrap glass, sticking, spotty, foggy ware results. The structure of a chill cast mold resembling in its finely dendritic pattern a

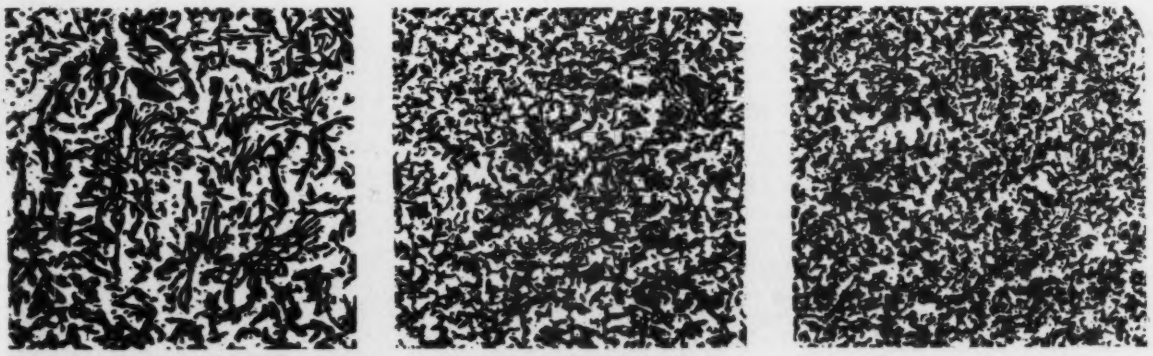
TABLE III

Silicon %	Total Carbon %
zero	4.30
1.0	3.95
1.5	3.80
2.1	3.60
2.4	3.50
2.7	3.40

TABLE IV. THERMAL CONDUCTIVITIES OF SEVERAL CAST IRONS

No.	TC	Si	Mn	Ni	Cr	V	*K 400
21	3.16	1.48	.97				.107
22	3.25	1.56	1.87				.104
23	3.32	1.52	2.43				.101
24	3.19	1.42	.96		.20		.112
25	3.17	1.40	.97		.40		.114
26	3.19	1.54	.99				.103
27	3.16	1.56	.94	.75			.101
28	3.30	1.89	.71	.25	.50	.013	.102
29	3.33	1.21	.64	.30	.61	.020	.103
30	3.41	1.03	..	1.50	.54		.104

*K=Cal/Cm/Sec.



WITHOUT NICKEL | WITH .73% NICKEL | WITH 2.12% NICKEL

Fig. 2. The refining effect of nickel on the grain of a high carbon gray iron. Cupola Iron: Carbon 3.50%, Silicon, 1.00%, Manganese .60%. Photomicrographs of abritration bars. X 30.

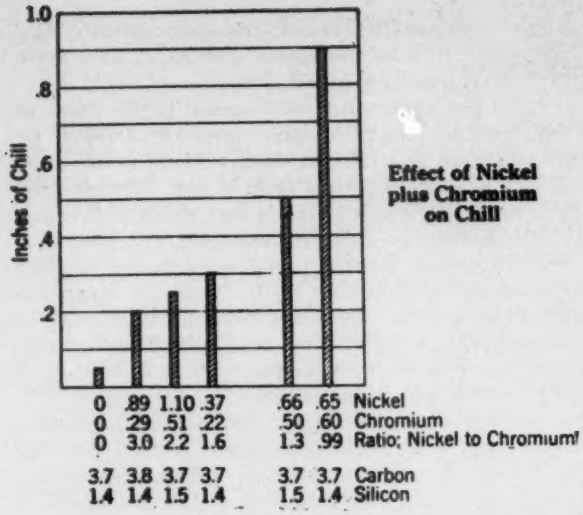

1.0
.8
.6
.4
.2
Inches of Chill
Effect of Nickel plus Chromium on Chill
0 .89 1.10 .37 .66 .65 Nickel
0 .29 .51 .22 .50 .60 Chromium
0 3.0 2.2 1.6 1.3 .99 Ratio; Nickel to Chromium
3.7 3.8 3.7 3.7 3.7 3.7 Carbon
1.4 1.4 1.5 1.4 1.5 1.4 Silicon

Fig. 3. Relation between chill depth (white, unmachinable surface) and nickel-chromium ratio indicating need for a low chromium content or a high nickel to chromium ratio to maintain freedom from chill and carbide formations. Also obtain the strength, grain refinement and density advantages of alloyed, high carbon mold irons with the same freedom from chill that prevails in the plain cast iron.

head of sun-flower seeds or a pin-filled pin-cushion, permits the surface to float in effect as the hot glass strikes. The impact effect of hot glass upon a mold surface leads to a natural tendency for the surface to swell or expand like a blister. The fine, columnar micro-structure of the chill cast mold cushions and dissipates some of this impact. A high concentration of graphite, somewhat directionally aligned perpendicular to the surface effectively arrests cracking and the deeply rooted grains seem to resist spalling or plucking at the surface minimizing pitting or fogging. These softer, chill cast irons lend themselves to the scraping and burnishing operations of a mold shop more readily than the harder, sand cast product. Irons 5 and 6 first with A and 4 second are leaders in the chill cast series (Table I) while C and 14 (Table II) lead the sand cast group.

ROLE OF GASES IN GLASS

(*Continued from page* 258)

be oxidized, later antimony and arsenic, cerium and manganese, and only if all these elements have formed their higher oxides, an excess of oxygen would be able to form chromate.

The oxygen distribution may be definitely changed if we go to glasses of extreme compositions or to extreme temperatures. At relatively low temperatures, for instance, MnO glasses have a pronounced tendency to react with oxygen forming the purple Mn_2O_3 glass. Under the influence of light such change in oxidation even takes place at room temperature (solarization).

Another factor which influences the distribution of oxygen among the above-mentioned oxides is their concentration in the glass. That may be illustrated by an example. A soda-lime glass containing small amounts of manganese increases its pink-purplish color on the addition of cerium, whereas a similar glass with a deep purple color due to about five per cent manganese can be faded by the addition of cerium oxide.

This concludes the discussion on the role of oxygen in fining and decolorizing. The next paper will similarly summarize the part which carbon dioxide plays.

ARMSTRONG COMPLETES PURCHASE

On June 20, following several months of negotiations, the purchase of the Whitall Tatum Co. of Millville, N. J., by the Armstrong Cork Co., Lancaster, Pa., was consummated. Reversing the usual procedure, one of the nation's leading closure manufacturers has entered the glass container field.

According to H. W. Prentis, Jr., president, Armstrong Cork Co., the purchase will affect only the sales departments and not the production set-up of Whitall Tatum. The plants of Whitall Tatum will be operated by the same management as heretofore. And while it is planned to combine the two sales groups, utilizing the personnel of both, no changes of a major nature in the distribution of Whitall Tatum products are contemplated.

Fred C. Tatum will remain with the company as manager of glass sales in the New York district and W. H. B. Whitall will act in the dual capacity of Philadelphia district manager and manager of the Whitall Tatum Co. department of Armstrong. D. L. Armstrong, vice-president in charge of Armstrong's Closure Division, will head the new Glass and Closure Division.

• "Silicosis in the Foundry Industry," by Dr. Leonard Greenburg, director of the division of industrial hygiene of the New York State Department of Labor, is the title of a recent booklet published by the American Foundrymen's Association. The results of the survey are based on figures obtained from the examination of over one-third of the workers in the industry in New York State employed in one-third of the foundry plants.

WINDOW CONDITIONING CAMPAIGN LAUNCHED

A broad advertising and merchandising campaign to focus attention upon the most important single form of insulation—window conditioning by means of double glass—is being started by the Libbey-Owens-Ford Glass Co. John D. Biggers, president of the company, points out that the 12,000,000 homes with central heating plants offer an immediate market for this type of window conditioning.

It is significant that Libbey-Owens-Ford does not contemplate a brief campaign but rather a program of carefully scheduled activities designed to build up interest over an extended period so as to assure increasing and permanent benefits for both the building industry and the ultimate consumer.

District sales managers of Libbey-Owens-Ford will be assembled from all over the United States for a special meeting in Toledo on June 28 to acquaint them with every phase of the campaign and to study the material prepared for inaugurating and maintaining it.

• Center of the display in the Hall of Science at the 1939 Golden Gate International Exposition will be a model of the 700-ton telescope now being installed on Mount Palomar in Southern California. It will be built exactly to scale with the 200-inch mirror duplicated by an eight-inch facsimile.

ELECTRIC MELTING OF GLASS

By Y. R. CORNELIUS

In considering the application of electric melting to the manufacture of glass, one must always bears in mind that it seeks to replace a method that has been through a period of development lasting almost a century. While experimental operations, such as that at St. Helens, England, in 1929, have greatly advanced the art; yet before it can conclusively demonstrate its commercial importance, the electric furnace must undergo a process of evolution somewhat similar to that passed through by the Siemens furnace.

Another factor retarding its progress has been the relatively high cost of electricity as fuel. This has been offset by certain economies; such as in the matter of repairs, which are fewer; and in a cheaper batch, using light instead of dense soda ash. But while these economies are definite and known, no performance records have been kept from which could be calculated the actual dollars and cents of the saving.

It is the purpose of this paper to report certain improvements in furnace design and operation, and to describe certain conditions under which a favorable power contract may be obtained.

The ideal conditions for the development of electric melting glass would include an experimental furnace of commercial size, operated for an indefinite period of time and with its output regulated at will. Such operation would provide the desired answers to most of the important questions; such as proper melting area, metal depth, electrode size and location, etc. The cost of such an experiment would, of course, be prohibitive. Conditions analogous to those desired exist, however, in the electric melting of sodium silicate, which operation has been conducted for over five years at the plant of the North American Cyanamid Co. at Niagara Falls, Ont.

Sodium Silicate Melting

The installation at Niagara Falls comprises two furnace units with capacities of 20 and 30 tons of sodium-silicate glass per day, respectively. The usual procedure, however, is to operate the furnaces alternately. All operations of the furnaces are automatic, the raw material batch being continuously charged and the product continuously discharged.

The furnaces are single-phase and of the direct-resistance type. A set of electrodes is located at each longitudinal side wall of the melting chamber, this chamber being separated by an air-cooled bridge wall from a smaller chamber. The molten charge in the melting chamber is covered by a blanket of raw material, so the melting chamber possesses no arch, except a temporary one employed while oil burners are used during the heating up period. The batch is delivered to the furnace by a motor-driven blanketing car. A more detailed description of this type of furnace, as applied to ordinary glass, will be given later.

Construction of the first unit at Niagara Falls began during the fall of 1932 and was completed in December of the same year. This first furnace operated for about four months and was then shut down, partly for necessary changes in design and partly to enlarge its capacity. Changes in design included reinforcement of the bridge wall, increase of electrode size, and relocation of the electrodes relative to the transverse walls of the melting chamber.

By courtesy of the American Cyanamid Co., two views of one of the Niagara units are shown. Fig. 1 shows the furnace covered with the temporary arch during the heating up period and it will be noted that the top of the furnace is flush with the second floor of the building. The picture was taken from the discharge end and the bin containing the mixed batch is seen in the background. Fig. 2 was taken from the same end, but closer. The temporary arch has been removed and the blanketing charging car is seen instead. At the front may be seen the covered discharge opening, through which the glass leaves the furnace in a pencil-thick stream and as viscous as light oil. The glass drops to a conveyor on the ground floor and is carried to storage.

A paper presented at the Fifth Conference on Glass Problems, University of Illinois, May 20, 1938.

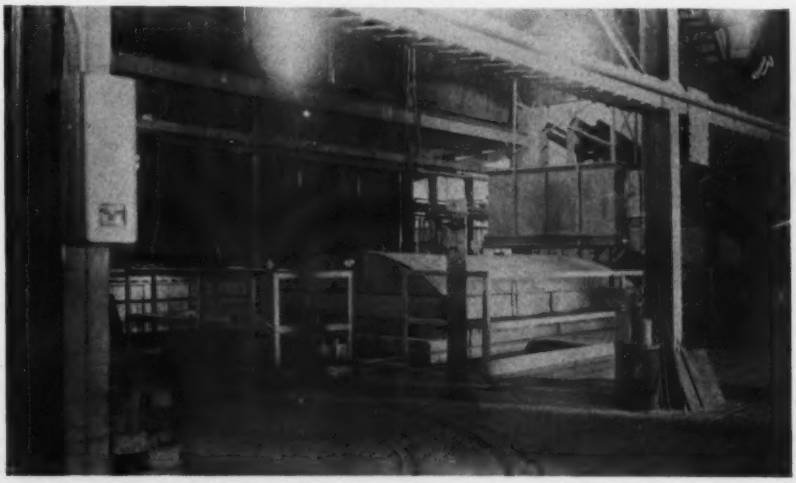


Fig. 1. Electric furnace for melting silicate of soda at the American Cyanamid Co., Niagara Falls, Ont. The melting end of the rear is covered with a temporary arch for heating up with oil.

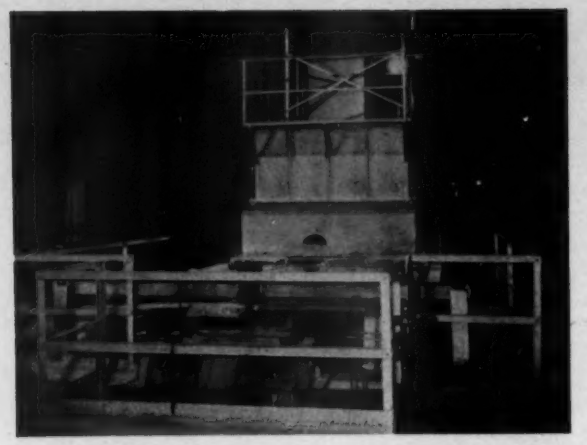


Fig. 2. Niagara Falls electric furnace in a closer view. The temporary arch has been removed and its place taken by the blanketing charging car.

Production at Niagara Falls was resumed in the latter part of June, 1933, and the enlarged and modified furnace operated continuously for 504 days, or almost 17 months, at an average of one ton of silicate glass per 6 square feet area of the melting chamber. Records for a later furnace showed a furnace life of 15 months and an average of one ton of silicate glass per 5 square feet melting area. However, the furnace averaged a ton per 4.5 square feet for about 7 months of this period.

The electric power consumption per short ton of silicate glass is from 800 to 825 kw. h., measured on the high-tension side of the step-down transformer. This is a broad average and not a top figure. A power consumption as low as 655 kw. h. per short ton, measured on the low-tension side, has been recorded for one month's operation.

These data apply equally to ordinary glass and, in fact, the power consumption is slightly lower for glass, provided the glass-batch includes 20 per cent of cullet.

The efficiency is remarkably high, even at greatly reduced capacity, and even more interesting is the smoothness and dependability of the operation at Niagara. The electric power is on continuously and the voltage is never changed, save for occasional settings to conform production with shipments. The management is able to anticipate the length of each operating campaign and has come to expect no trouble during operating period.

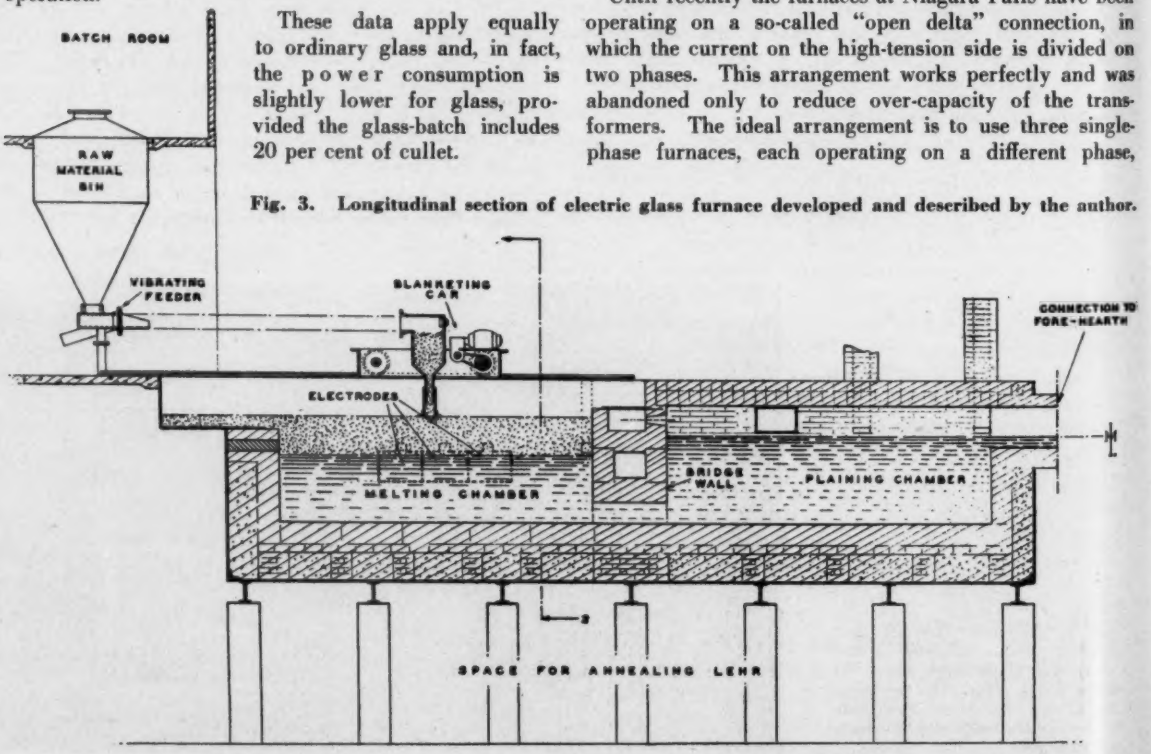
Single-Phase vs. Three-Phase

Before going further, a few words about single and three-phase furnaces: if the capacity of the power line is sufficient, the single-phase furnace is at all times preferable to the three-phase furnace. The necessity for a balanced load is grossly exaggerated, because most power lines are today of such capacity that an additional load of 500 kw. on one phase is scarcely noticeable.

Safe operation depends largely on low current density at the electrode surface, and this cannot be obtained to the same degree in a three-phase as in a single-phase furnace. If an equalized temperature is desired in a three-phase furnace with stationary electrodes, it is only possible to obtain a balanced load at a certain draw or capacity. Above or below that capacity the load will be unbalanced. Furthermore, good operation of a three-phase furnace may be impaired by an already existing unbalanced load due to some other operation on the same power line. The temperature in two of the electrode gaps may thus increase, while it drops in the third, and the bad condition grows worse with passage of time until the current may flow in two gaps entirely, leaving the third cold. Conditions of this kind make it uncertain just where the current flows in the three-phase furnace and raise the question of what causes localized areas of the furnace lining to be prematurely destroyed.

Until recently the furnaces at Niagara Falls have been operating on a so-called "open delta" connection, in which the current on the high-tension side is divided on two phases. This arrangement works perfectly and was abandoned only to reduce over-capacity of the transformers. The ideal arrangement is to use three single-phase furnaces, each operating on a different phase,

Fig. 3. Longitudinal section of electric glass furnace developed and described by the author.



with a fourth spare furnace ready for operation whenever one of the other furnaces goes down for relining. The same condition may be obtained with two furnaces, and a third as a spare, by converting the three-phase current to two-phase by means of a Scott-connected transformer.

For larger tanks used in the manufacture of plate and window glass, electric furnaces may be used as premelters. Such a tank might be designed with four single-phase, pre-melting furnaces supplying a fuel-fired plaining section. The four pre-melters would be operated in rotation, as explained above. The plaining section lasts at least three times as long as the melting section in an ordinary tank, so the pre-melting arrangement should produce a considerable operating economy.

The Electric Glass Furnace

A typical electric glass furnace of the system developed by Erik Cornelius and the author, seen in Fig. 3, illustrates batch-feeding and a longitudinal section of the furnace itself. Fig. 4 is a cross-section of the furnace on the line 2-2, Fig. 3, showing the melting chamber, the batch blanketing car and the raw material bin.

At the rear end of the furnace and on the upper floor is located the raw material bin. The bin has a dust-tight connection with the batch mixing room above, so that no batch dust will enter the furnace building. The width of the bin equals the inside width of the furnace and the lower end of the bin conforms to an open slot, fitted into a vibrating feeder which supplies the batch to the blanketing car.

The blanketing car incorporates a four-wheeled carrier, driven by a geared motor, and a hopper with a spout-like bottom part, the latter being surrounded by a vertically adjustable extension. The upper part of the hopper also has an opening which corresponds to the vibrating feeder. When batch is fed, the connection between the vibrating feeder and the car is sealed by rubber packings to prevent dusting. With this apparatus an even blanket of raw-material batch is maintained above the molten glass in the melting section of the furnace and, by raising or lowering the adjustable extension on the blanketing car, different thicknesses of blanket can be obtained.

The furnace shown is single-phase, this being the preferred form. However, large scale experiments on three-phase operation have been carrid out and in these the furnace design differs only in the location of the electrodes. In a three-phase furnace the electrodes are placed at each of the four side walls of the rectangular melting chamber to form a "double delta."

The furnace itself includes a steel casing, on the bottom of which transverse checker walls of fire brick are placed for the purpose of supporting the bottom tank blocks. These checker walls are spaced so that their centers are in line with the transverse joints of the bottom tank blocks and the spaces between the checker walls are filled with dry sand for insulation. On top of the checker walls and the sand is a course of 9-in. fire bricks on edge, serving as the foundation for the bottom blocks and the side walls. There are two furnace chambers, a melting chamber and a plaining chamber, separated by an air-cooled bridge wall. The plaining chamber actually represents both the plaining zone and the working end of a fuel-fired tank.

In the melting chamber at each longitudinal side wall, a shelf or platform, 12 in. wide and 18 to 24 in. high, is built up from the furnace bottom with refractory blocks. Upon these shelves, or platforms, the electrodes are set. The electrodes are made of pure, low-carbon iron and consist of rectangular blocks and vertical connection plates. The blocks extend into the molten glass, the connection plates rising into the batch blanket and extending horizontally through the furnace side walls to the busbars outside the furnace. The connection plates rise about 6 in. into the batch blanket and each has a thickness of 6 inches. The purpose of this arrangement is to subject the electrodes to a certain amount of cooling.

The batch blanket covering the glass in the melting chamber has a minimum depth of 14½ in., below which depth excessive radiation losses occur. Above 14½ inches its depth may vary within a range of approximately 12 inches. The blanket thickness may be varied chiefly for two reasons: (1) to effect a change in the electrical conductivity of the bath, and (2) to adjust the metal level in the working end of the furnace.

The space between the vertical side walls and the steel casing is insulated either by dry sand or by porous fire bricks. Dry sand was the original insulation and may still be preferable because it acts as a check on any molten glass penetrating behind the refractory walls, whereas porous fire bricks are dissolved by such glass. The plaining chamber, which also constitutes the working end, is heated solely with oil burners located above the bridge wall, and the length of the heating zone may

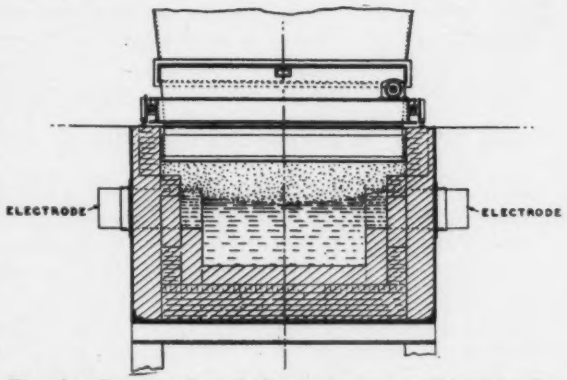


Fig. 4. Cross section of electric furnace melting chamber on line 2-2, Fig. 3, showing position of electrodes.

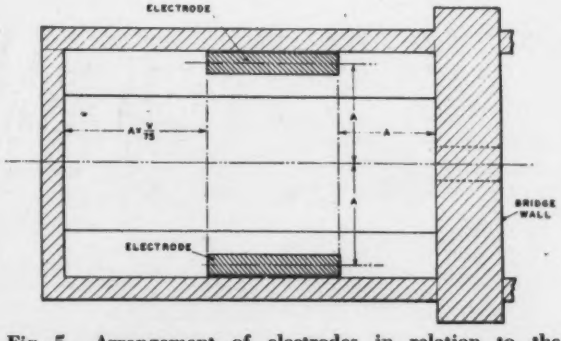


Fig. 5. Arrangement of electrodes in relation to the transverse furnace walls.

be adjusted by spaced stack openings in the side walls. The annealing lehrs may be placed under the furnaces, thus providing more accessibility to the forming machines, better ventilation and better light.

Major Improvements Since St. Helens

The St. Helens experiment on electric melting of glass was extensively described by Mr. Meigh in his presidential address to the Society of Glass Technology in 1931. It may be of interest to review here the major changes and improvements in furnace design that have been accomplished since that time.

The discovery of the indifference of the batch to the iron electrodes was probably most important. It was previously feared that contact between batch or semi-fused batch and the iron electrodes would result in oxidation of the electrodes, but these fears were, however, completely dispelled by the operation at Niagara Falls. The electrodes are there in constant contact with the batch, but the increase of the iron content in the glass from the electrodes is less than 0.005 per cent. This is positively proven by the fact that, had the increase in iron content been as high as 0.015 per cent, the electrodes would long ago have been dissolved in the glass.

Establishment of the fact that the electrodes are not damaged by direct contact with the batch opened avenues for furnace modifications heretofore considered closed and forms the basis for some of the modifications related hereafter. In Fig. 5 the location of the electrodes in relation to the transverse side walls of the furnace is shown. The electrodes are spaced a distance A from the bridge wall and the distance A equals half the distance between the center lines of the opposing electrodes. A slightly greater distance is needed between the electrodes and the rear wall and it has been found suitable to make this increase a function of the average operating voltage. Thus, the distance A is multiplied by $\frac{V}{75}$, in which V stands for the average operating voltage of the furnace when the voltage exceeds 75. This arrangement of electrodes and side walls is the result of post mortem examinations of the furnaces when shut down for relining. To begin with, the transverse walls constituted the weakest part of the furnace, and deterioration of these walls by the electric current resulted in early shut down for relining, but in the present arrangement this damage is eliminated and a more even wear of furnace lining is obtained.

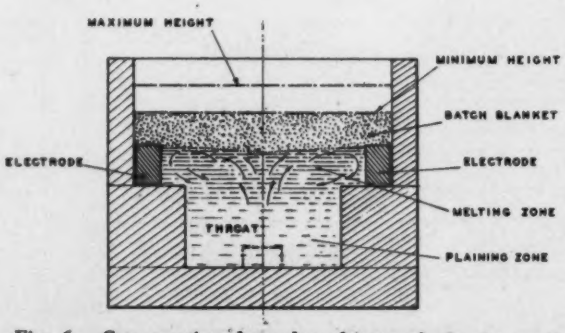


Fig. 6. Cross section through melting end, showing melting and plaining zones and convection currents.

In the St. Helens furnace and in the first furnace at Niagara the electrode connections consisted of horizontal plates placed under the cubical portions of the electrodes. Then when the shelves or platforms upon which the electrodes rested wore off, the electrodes sagged, the electrode gap narrowed and the heat distribution was disturbed. Furthermore, the electrode connection plates were severely damaged. The new type of vertical connection plate extending into the raw material blanket is cooled by the blanket and generally holds the rectangular portions in place. This part of the electrode and the vertical connection plate are cast in one piece.

In the St. Helens furnace the electrodes were placed on the bottom of the melting chamber and the electric current was converted into heat in the section of the glass nearest the bottom. This location of the heating zone resulted in a stimulated convection of the glass and, while it improved the homogeneity of the glass, it had a bad effect on its seed condition.

Fig. 6 shows a section of the present design of melting chamber, in which this condition has been modified. The electrodes are set on two shelves or platforms running along the side walls, these shelves being so high that the tops of the electrodes reach the sintered batch. In this manner the heating zone is moved upward to a point immediately below the batch blanket and the convection in this zone helps to increase the speed of melting. Between the shelves the heavier glass, cooler than that in the melting zone, will move downwards and will not take part in the convection in the melting zone. While there were two zones, batch blanket and melting zone, in the St. Helens furnace, there are three zones in the present one, namely: batch blanket, melting zone and a plaining zone further below.

By the arrangement shown in Fig. 6 it is also possible to adjust the temperature of the glass in the melting chamber. As stated earlier, a minimum batch blanket thickness of 14½ in. is required in order to avoid radiation losses. When the blanket thickness is increased the conductivity of the bath will drop and a higher glass temperature can then be obtained by bringing back the electrical conductivity through a momentary reduction in the draw of glass from the furnace. The opposite condition can be obtained by reducing the blanket thickness and momentarily shutting off the electric current supply to the furnace.

Cost of Electric Melting

The price for electric power has generally been considered too high to allow electric melting of glass. This impression may have arisen through a too casual approach to the subject and it is probable that the high cost has been taken too much for granted. Electrification of the glass industry would require annually about 250,000 h.p.-years, or several million dollars worth of electricity. The electric power companies should, therefore, be as interested in the future of electric melting as the glass industry itself and should take tomorrow's earnings into consideration when establishing today's prices.

However, without taking future power prices into consideration a reasonable power rate may be obtained today by operating the glass furnaces on "off peak" power, for which the present furnace is especially suitable. Fig. 7 is a graphic demonstration of such "off peak" operation

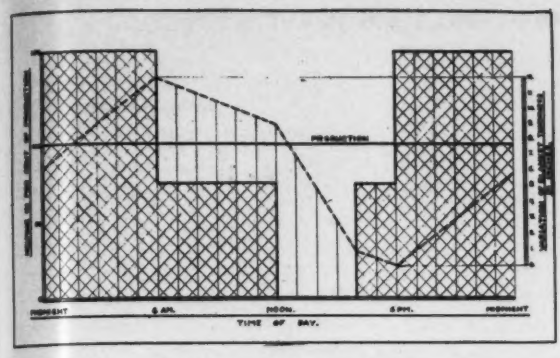


Fig. 7. Chart showing requirements for operation on off-peak load power and adjustment of batch blanket.

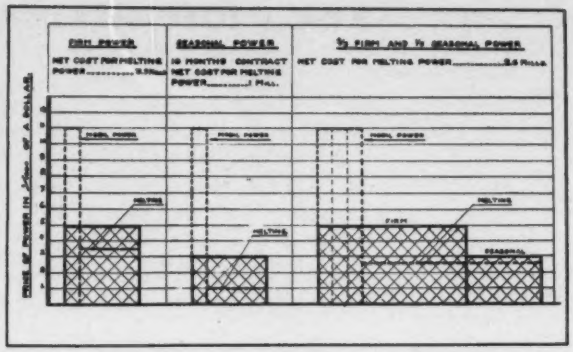


Fig. 8. Chart showing cost calculations and blending of firm and seasonal power.

during a 24-hour day. The straight line across the diagram marked "production" signifies an even draw of glass from the furnace, while the shaded surfaces represent rate of melting in percentage of the production. As seen on the diagram, from 6 P.M. to 6 A.M. the melting is boosted to a rate of 150 per cent of the production, meaning that half as much more is melted than is drawn out of the furnace. During two periods of the day, from 6 A.M. to noon and from 4 P.M. to 6 P.M., the melting is reduced to 75 per cent of production and between noon and 4 P.M. the electric current is off altogether. During the entire 24 hours the metal level in the working end is maintained constant by regulating the thickness of the batch blanket. The broken line on the diagram indicates the variation in blanket thickness during the day, the total variation being 12 inches, which amount should, of course be added to the minimum thickness of 14½ inches.

The blanket regulation does not involve any complications and the metal level is always under control. When the blanketing car is stopped the metal level will recede regardless of the rate of melting. When the furnaces are operated according to a schedule similar to that shown in Fig. 7, the power may be obtained for about 4 mills per kw. hour.

In a bottle plant, electric power is used for various purposes such as compressors, conveyors, mixing equipment, lights, etc., which for identification may be called "mobil power." This power totals about 25 per cent of the power which would be required for electric melting and its cost is quite high, averaging about 11 mills per kw. hour. This power may be included when contracting for power for electric melting, but must, of course, be available every hour of the day, so the contract must specify 20 per cent firm power and 80 per cent "off peak" power.

In addition, the power companies usually have available a seasonal power that is firm for about 10 months of the year and which may be contracted for at a price around 3 mills per kw. h. A certain amount of this type of power may also be used in an electric glass plant.

Three examples of these types of power and their blending are charted in Fig. 8. "Firm" power in this figure means 20 per cent actually firm and 80 per cent off peak, and by "seasonal" power is meant power available during 10 months of the year.

In the first example firm power is purchased for 5 mills. If the melting power is credited with the 6 mills saving secured for the mobil power, the cost for melting will be 3.5 mills per kw. h. or $2.80 per short ton of glass produced.

In the second example seasonal power for 10 months is obtained for 3 mills. The saving on mobil power is then 8 mills and, when this is credited to melting, the melting cost is reduced to 1 mill per kw. h. or 80 cents per ton of glass.

The third example proposes a blending of ⅔ of firm power at 5 mills and ⅓ seasonal power at 3 mills. For instance, two furnaces operating 12 months of the year and one furnace 10 months of the year. The two idle months may be used for relining all three furnaces. In this case the cost of melting, including credit for cheaper mobil power, will be 2.6 mills or $2.08 per ton of glass. From these cost figures 25 cents per ton of glass may also be deducted for the use of light instead of dense soda ash.

The above cost calculations have been made in an endeavor to prove that the melting of glass can be done electrically in competition with other fuels. In addition, there are many other possible savings, through such factors as less repairs, lower original investment, less damage to machines because of improved dust condition in the plant, etc., but estimates of these would be mere speculations at the present time.

In conclusion it may be said that further progress in electric melting depends on the willingness of the industry itself to provide more operating opportunities, not only for the development of another furnace for melting glass, but also for what may be gained in improved plant design and better working conditions.

NEW ENGINEERING COMPANY FORMED

The formation of the Loftus Engineering Corporation, 509 Oliver Building, Pittsburgh, has been announced. This is an independent engineering organization established to handle all problems relating to the application of the Loftus checker system for regenerative furnaces. Fred H. Loftus, who has had long experience in the furnace field, is president.

SUMMER COURSE AT ALFRED

Dr. Samuel R. Scholes writes that courses in petrography and in a survey in glass technology are available at the New York State College of Ceramics, Alfred, N. Y. Since the session is scheduled to begin July 5, it is important that all interested communicate immediately with Waldo A. Titsworth, Registrar, Alfred, N. Y.

THE PROPERTIES OF GLASS STONES

Scattered throughout technical literature on glass are numerous papers describing the properties, occurrence and identification of the various types of stones found in commercial glasses. A petrographer who is constantly working with glass stones does not usually find it necessary to refer to this literature, but the glass technologist may be called upon to identify stones only occasionally. Then it is often necessary to spend much time searching for sufficient information to properly identify the type and source of the stones in question.

As a guide to the glass technologist, information about the properties of the more common types of stones has been collected here and rewritten in concise form. The following presentation lists the physical characteristics, the optical properties and the mode of occurrence of the common devitrification, batch and refractory stones. When identifying stones by the thin section method, the listed physical characteristics and the occurrence remarks will assist materially in the identification. Likewise, the constants and remarks given under the optical properties, coupled with those found under occurrence, will be of considerable help when the grain method of identification is used.

Quartz (SiO_2)

Physical Characteristics: Hexagonal. In glass stones it has no definite shape because such stones usually consist of undissolved sand grains.

Optical properties: Ne = 1.553, No = 1.544, uniaxial and positive.

Occurrence: Quartz is the stable form of silica below 870°C. In glass it is usually found as batch stones, in scum or in refractory stones and has never been observed as a devitrification product. In batch stones it may exist as undissolved or partly dissolved sand grains, sometimes associated with a tail of silica cord. Since the cord is rich silica it will often devitrify if conditions permit, and tridymite skeleton crystals will be found in the glass comprising the cord. In scum stones there is usually a core of unaltered quartz surrounded by a layer of cristobalite or cristobalite and tridymite. In refractory stones it is usually associated with dehydrated clay substance, mullite and other refractory material.

Cristobalite (SiO_2)

Physical Characteristics: Tetragonal (pseudo-isometric). Crystals octahedral or skeletal, sometimes arranged in parallel growths on a cubic pattern. When free to grow it may form elongated cubes. Often observed as pine-tree growths or lamellar, twinned grains.

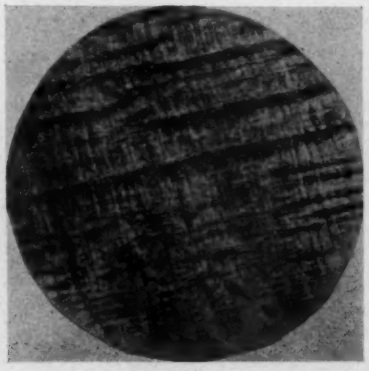
Optical properties: No = 1.487, Ne = 1.484; No-Ne = 0.003. The uniaxial form is negative. Due to the compensating effect of intricate twinning, cristobalite usually appears to be nearly isotropic.

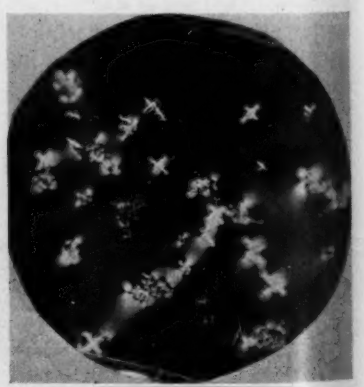
Occurrence: Although cristobalite is the stable form of SiO_2 above 1470°C, it can appear at lower temperatures, sometimes crystallizing directly from the melt. It is often an intermeriate crystalline form of silica in the inversion of quartz to tridymite. (Fig. 1) Cristobalite is usually found in batch stones, scum stones or devitrification stones. In batch stones it is nearly always associated with tridymite and undissolved grains of quartz. In scums it is usually associated with tridymite and predominates in the lower layers of the scum. When formed through devitrification it usually appears as pine tree growths. Cristobalite also may form at the glass contact layer in cases where the refractory block is of highly silicious type. Its low index of refraction (lower than the refractive index of the usual soda-lime-silica glass), together with its characteristic skeleton crystals and parallel growth, makes cristobalite very easy to identify. (Fig. 3).

Tridymite (SiO_2)

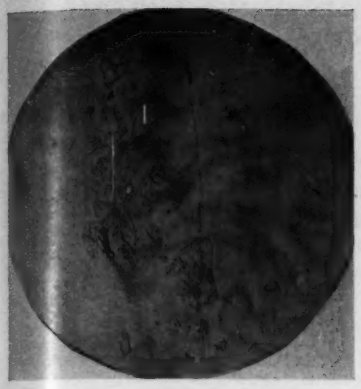
Physical Characteristics: Orthorhombic (pseudo-hexagonal). Crystals are usually thin hexagonal plates appearing as needles or laths. Frequently shows characteristic parallel growth of overlapping plates and often appears as wedge or arrow shape and interpenetration twins. Plates arranged in parallel layers are often found.

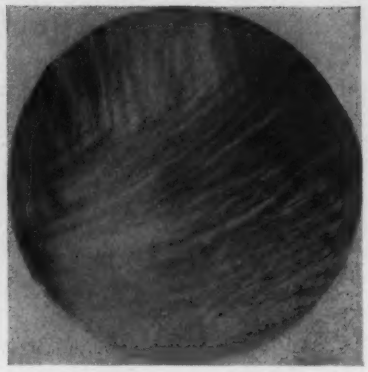
Optical properties: Ng = 1.473, Nm = 1.469, Np = 1.469. Biaxial positive with the acute bisectric normal to the hexagonal plate. When on edge the plates appear as needles or laths which have parallel extinction and negative elongation (elongation = a). Occasionally





Left to right: Fig. 1. Cristobalite-Pinetree growth due to devitrification. Fig. 2. Cristobalite due to scum. Fig. 3. Cristobalite stones in a devitrified glass. (Polarized light.)





Left to right: Fig. 4. Tridymite-Anhedral type due to devitrification. Fig. 5. Tridymite-Wedge shaped needles found in scum. Fig. 6. Devitrite due to devitrification.

pseudo-isometric forms may be found and are probably due to inversion from cristobalite.

Occurrence: Tridymite is the stable form of silica between 870°C. and 1470°C. Found in batch stones, scum stones, devitrification stones and crown drops. (Fig. 4) In batch stones it is usually associated with cristobalite and quartz in the form of hexagonal plates or wedge-shaped twins. In scums due to silica, tridymite usually appears as hexagonal plates, wedge-shaped twins, or both, and is predominate in the upper layers of the scum. (Fig. 5) In devitrification stones it appears most often as hexagonal plates arranged irregularly in a matrix of glass. In crown drops tridymite usually appears as large wedge-shaped crystals or as intricate twins and hexagonal plates.

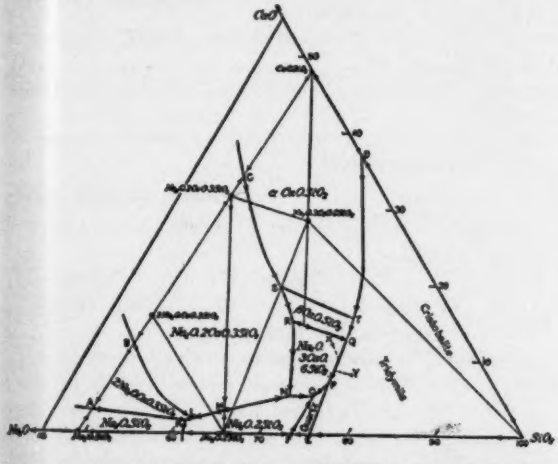


Fig. 7. Crystallization diagram of the system $Na_2O.SiO_2$-$CaO.SiO_2.SiO_2$. From Morey and Bowen, J. Soc. Glass Tech., 9, pp. 226-264, 1928, on a weight per cent basis. Arrows indicate directions of falling temperatures.

Devitrite ($Na_2O.3CaO.6SiO_2$)

Physical characteristics: Orthorhombic. Occurs as slender prismatic crystals having hexagonal or octagonal cross-section, or as needles. Sometimes found in the form of nodules.

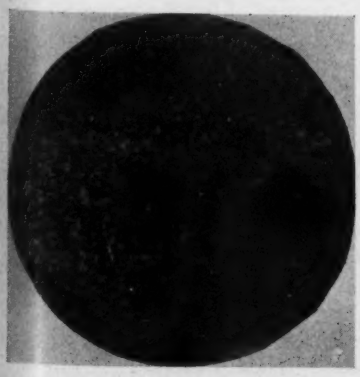
Optical properties: Np = 1.564, Nm = 1.570, Ng = 1.579. Parallel extinction and negative elongation.

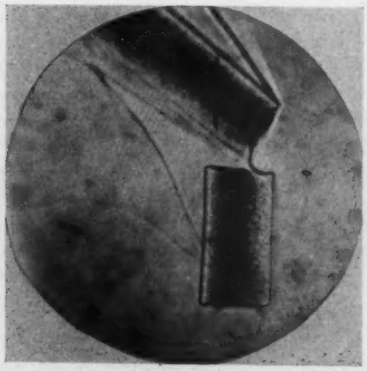
Occurrence: Devitrite, as its name implies, is a devitrification product and can only exist in the melt through a small range of temperature without dissociation. While it decomposes at 1047°C it can exist in pure Na_2O-CaO-SiO_2 mixtures at temperatures as low as 725°C. (See Fig. 7) It is usually formed in the stagnant areas of the tank furnace, either in dead corners or on the tank bottom.

Wollastonite ($CaO.SiO_2$)

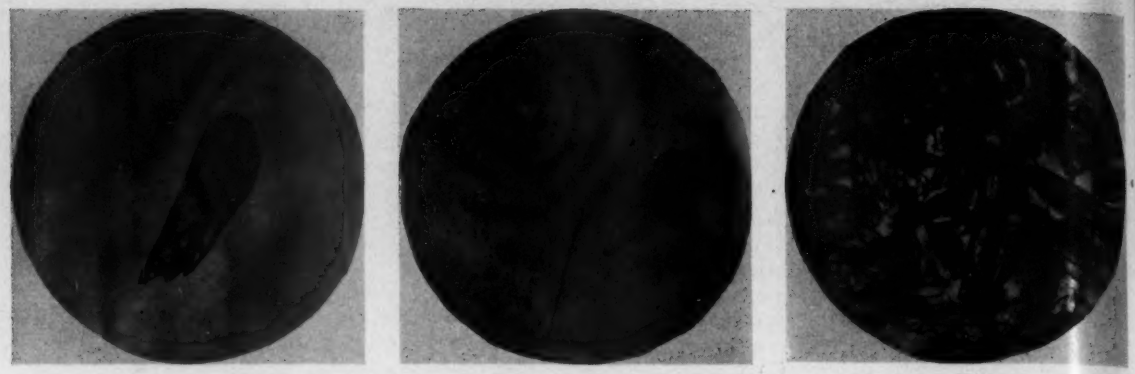
Physical Characteristics: Monoclinic. In glass it appears as needles or laths.

Optical properties: Ng = 1.631, Nm = 1.629, Np =





Left to right: Fig. 8. Wollastonite due to devitrification. Fig. 9. Nepheline-Worm type stone due to reaction of sodium silicate liquid and refractory. Fig. 10. Nephelite—Precipitated type. (Polarized light.)



Left to right: Fig. 11. Kyanite stone. Fig. 12. Corundum crystals from above the glass line. Fig. 13. Corundum layer from refractory block above glass line.

1.616. Biaxial negative. Elongation is either positive or negative depending upon the plane in which the lath is turned.

Occurrence: Wollastonite can occur only as a devitrification product, usually appearing as radiating feathery or spherulitic aggregates. (Fig. 8) While wollastonite is stable at temperatures below 1170°C., it inverts to pseudo-wollastonite at temperatures above 1170°C.

Pseudo-Wollastonite ($CaO.SiO_2$)

Physical Characteristics: Monoclinic. Crystals appear as grains.

Optical properties: Ng = 1.654, Nm = 1.611, Np = 1.610.

Occurrence: See wollastonite.

Diopside ($CaO.MgO.2SiO_2$)

Physical Characteristics: Monoclinic. Crystals usually as short slender prisms or grains.

Optical Properties: Ng = 1.69, Nm = 1.67; Np = 1.66. Biaxial positive. Maximum extinction angle of about 40 degrees.

Occurrence: A devitrification product or scum from glass batches employing dolomitic lime. Usually appears as a spherulite in the case of devitrification. Diopside stones due to scum are usually found as streaks or patches of closely packed crystals.

Note: Monticellite ($CaO.MgO.SiO_2$) and Akermanite ($2CaO.MgO.2SiO_2$) have both been mentioned as possible devitrification products of glasses containing dolomitic lime. While their occurrence (Akermanite at least) is common in slags and artificial melts, they are both rare in commercial glasses and would probably be formed only under exceptional circumstances. Jeffersonite (Diopside containing MnO and ZnO) has, however, been found as a devitrification product in some special-composition calcia-magnesia glasses.

Barium Disilicate ($BaO.2SiO_2$)

Physical Characteristics: Orthorhombic. Occurs as thin six sided plates.

Optical Properties: $\gamma = 1.617$; $\alpha = 1.598$. Parallel extinction and negative elongation.

Occurrence: A devitrification product of barium glasses. Appears as spherulites having a radiating fibrous structure.

Alamosite ($PbSiO_3$)

Physical Characteristics: Monoclinic. Occurs as fibrous crystals.

Optical Properties: Ng = 1.968, Nm = 1.961, Np = 1.947. Parallel extinction. Negative optic sign.

Occurrence: A devitrification product of lead glasses. Appears as spherulite having a radiating fibrous structure.

Willenite (Zn_2SiO_4)

Physical Properties: Trigonal. Occurs in glass as hexagonal prisms.

Optical Properties: No = 1.694, Ne = 1.723. Uniaxial positive.

Occurrence: Occurs only in zinc-containing glass as a devitrification product.

Mullite ($3Al_2O_3.2SiO_2$)

Physical Characteristics: Orthorhombic. Occurs in glass as needles.

Optical Properties: Ng = 1.654, Nm = 1.644, Np = 1.642. Z = C and (+) 2V = 45°. Slightly pleochroic; X = Y = colorless, Z = rose pink.

Occurrence: Occurs in glass as a refractory stone or as a batch stone, if improper grain size of kyanite is used as a source of alumina in the batch. In refractory stones from above the glass line the mullite crystals are large and are usually associated with large corundum crystals. In the case of refractory stones from below the glass line, and originating from the hotter parts of the furnace, the mullite crystals are more predominate and smaller in size than those from above the glass line. Corundum and nephelite are usually present. In refractory stones from the cooler portions of the furnace the mullite crystals may vary from large to minute in size but are usually in closely packed masses. Only a few corundum crystals and, in some cases, undissolved quartz grains from the clay may be present.

If sillimanite or kyanite grains are used in bonded refractories, mullite crystals due to the inversion of these two minerals may be found as stones in the glass, if an inferior bond has been used in the refractory.

Nephelite ($Na_2O.Al_2O_3.2SiO_2$)

Physical Characteristics: Hexagonal. Occurs in glass as grains or skeleton crystals.

Optical Properties: Ng = 1.532 to 1.544, Np = 1.536 to 1.549. Uniaxial negative. Double refraction low.

Occurrence: Nephelite occurs in glass as refractory stones, recrystallization stones and reaction stones. (Fig. 9.) In refractory stones corundum, mullite, or both, may be associated with the nephelite. In recrystallization stones the nephelite is caused by recrystallization from a glass formed by the solution of corundum or mullite material. In reaction stones the nephelite is formed as the result of a combination of silica with the proper proportions of soda and alumina. (Fig. 10.) For example, if the batch dust reacts with the silica brickwork an alkaline silicate liquid is formed which, if sufficiently fluid, will drip or run over the refractories picking up sufficient alumina to create the nephelite composition.

Nephelite is the low temperature phase of the mineral $Na_2O.Al_2O_3.2SiO_2$. Carnegite is the stable phase above 1350°C but inverts to nephelite on cooling.

Carnegite ($Na_2O.Al_2O_3$. $2SiO_2$)

Physical Characteristics: Triclinic. Lamellar. Almost always shows multiple twinning.
Optical Properties: Ng = 1.514, Nm = 1.514, Np = 1.59. Biaxial, negative.
Occurrence: Occurs in glass under unusual conditions. See Nephelite.

Kyanite ($Al_2O_3.SiO_2$)

Physical Characteristics: Triclinic. Crystals usually tablets or grains with rounded edges.
Optical Properties: Ng = 1.729, Nm = 1.722, Np 1.717. Moderately birefringent. Pleochroic in thick sections (0.5 to 1.0 mm.). X = colorless, Y = violet blue, Z = dark cobalt blue.
Occurrence: May occur in glass as a refractory stone from imperfectly inverted and poorly bonded kyanite grain refractories. If kyanite of improper grain size is used in the glass batch (Fig. 11) as a source of alumina it is possible to obtain batch stones consisting of unaltered kyanite if the furnace temperature is too low. Kyanite inverts to mullite and glass at temperatures above 1300°C. Grains of kyanite in glass will therefore often show a partial inversion to mullite. If the kyanite grain has undergone some solution in the glass the area surrounding the stone may consist of nephelite.

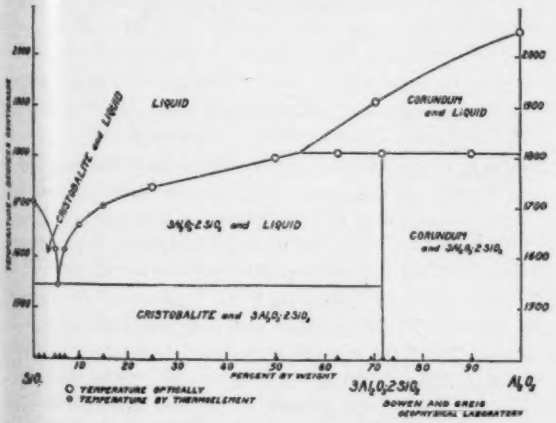


Fig. 14. Equilibrium diagram of the system Al_2O_3-SiO_2. From Bowen and Grieg, J. Amer. Cer. Soc., 7, p. 242, 1924.

Sillimanite ($Al_2O_3.SiO_2$)

Physical Characteristics: Orthorhombic. Crystals nearly square long prisms, but may show rounded edges.
Optical Properties: Ng = 1.677 to 1.684, Nm = 1.658 to 1.660, Np = 1.657 to 1.661. Birefringence is rather strong. In thick sections it is pleochroic, X = brownish, Y = green, Z = blue.
Occurrence: May occur in glass as a refractory stone from imperfectly inverted and poorly bonded sillimanite grain refractory. Sillimanite is stable below about 1545°C, dissociating into mullite and liquid at this temperature. If heated to 1810°C it dissociates to corundum and liquid. Sillimanite grains in glass may be partly converted to mullite. If the grain has undergone some solution in the glass the area surrounding the grain may consist of nephelite.

Corundum (Al_2O_3)

Physical Characteristics: Trigonal. Crystals usually are thin hexagonal plates which appear as fine needles when viewed on edge.
Optical Properties: Ng= 1.768, Ng = 1.760. Uniaxial and negative. When on edge, i.e., in the needle form, the needles show positive elongation. The birefringnce is weak.
Occurrence: The main source of corundum stones is the refractories or other clay material in the furnace walls. Clay materials above the glass line react at the high temperatures encountered in glass practice with both the batch dust and the volatilized soda in the furnace atmosphere forming corundum and a soda-alumina-silicate liquid. (Fig. 12.) This liquid may flow or drip into the glass carrying with it the crystals of corundum. As

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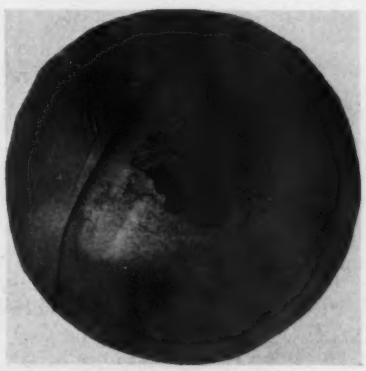
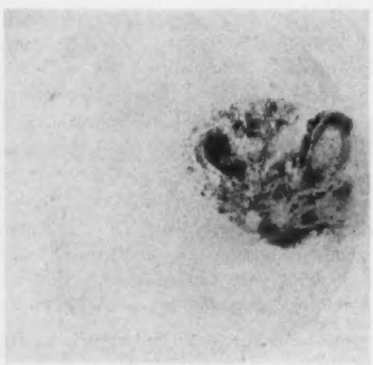




Left to right: Fig. 15. Nephelite and corundum in a glass knot. Fig. 16. Fire clay stone—shows little conversion or reaction.

GLASS NEWS FROM ABROAD

United States exports* of glass and glass products during 1937 were valued at $9,784,000, which represented an 18 per cent increase over 1936 and brought the industry up to within 11 per cent of the 1929 high.

The Canadian-Newfoundland area continued to be the most important foreign market for American glass, increasing its purchases by 19 per cent over 1936 to $4,328,859 or within 15 per cent of the 1929 total. The Central America-West Indian area was second with a 35 per cent increase in sales over 1936 to $2,123,000; this was 20 per cent larger than the 1929 trade. South American purchases of American glass products increased by 24 per cent over 1936 to $888,000 but were 17 per cent below 1929. Exports to the Near and Far East declined to $516,978 or one per cent below the 1936 figure and 45 per cent under 1929. Shipments to Europe were valued at $438,940, a gain of eight per cent over 1936, but 39 per cent below 1929. Exports to African areas rose one per cent over 1936 to $377,000, or more than double the 1929 trade.

All glass export classifications, except plate glass and electric insulators, shared in this increased trade in 1937. On a percentage basis, exports of lamps, chimneys and globes made the greatest gains with a 64 per cent increase over 1936. Other leading groups were unfilled glass containers (up 35 per cent), tableware (up 28 per cent), and chemical glassware (up 24 per cent). Sales of the last two surpassed 1929 totals. On a value basis, the container and tableware branches led in both total export sales and increases over 1936.

Several developments took place in the American glass trade with individual countries during 1937 which merit attention. For the most part the trend was highly favorable, although certain adverse factors can be noted. Canada, Cuba and Mexico (which account for over 60 per cent of the total glass exports) increased their purchases considerably, despite the fact that 1936 was a banner year. Cuban purchases rose by 40 per cent, Mexican by 34 per cent, and Canadian by 18 per cent. Shipments to four smaller markets, France, British East Africa, Hong Kong, and Norway, were more than double those in 1936, while Colombia, Chile, Honduras, and Nicaragua upped their imports of American glass by 50 per cent or more. Sizable increases were also reflected in Panama, Venezuela, Argentina, Peru, Costa Rica, Newfoundland, Guatemala, and Uruguay.

Perhaps the most unfavorable trend reflected by trade statistics was the decline of 22 per cent in sales to Brazil. Practically all types of glass suffered losses in this market, despite the reported growing demand in Brazil for foreign-made glassware. According to the American Consulate General at Sao Paulo, United States glass exporters are losing ground because of "lack of knowledge of general market conditions, business methods, packing requirements, etc., and more recently, to hesitancy on the part of the exporters to make shipments, owing to an uncertain exchange situation." Australian purchases of American glass products were also lower in 1937 than in 1936, but it is believed that this situation has been materially improved by relaxation of the import quota restrictions. Glass exports to China and Japan declined, owing, no doubt, to the unsettled conditions which have prevailed there.

From time to time the question is raised as to the extent to which American glass manufacturers have increased their export sales as the result of trade agreements concluded under the Reciprocal Trade Treaty Program. Since this program is not yet completed and many treaties have not been in force long enough to provide a statistical basis for comparison, it is difficult to answer the question categorically. However, it might be pointed out that while exports of glass products to all countries have experienced a substantial increase in the post-agreement period in comparison with the pre-agreement period, shipments to Canada and Cuba, the chief glass markets covered by tariff concessions under trade agreements, have increased at an even greater pace.

Furthermore, a complete study of United States exports of glass containers reveals that shipments to trade agreement countries, which take aproximately two-thirds of our exports of these commodities, have increased 62 per cent and non-agreement countries only 55 per cent for the post-agreement period (1936-1937) over the pre-agreement period (1934-1935). So it may be safely concluded that the Trade Agreements Program has apparently provided some stimuli to the sale of American glass products abroad.

Belgium: During March, 1938, there was very little activity in the Belgian window glass industry, orders being even scarcer than in February. It is interesting to note that whereas the output of Belgian window glass has declined steadily since 1930, along with that of Great Britain and Czechoslovakia, German exports of window glass have risen since that date. This appears to be due chiefly to the mechanization of the German plants which has enabled them to reduce their prices materially.

Czechoslovakia: Since the trade agreement between the United States and Czechoslovakia became effective April 16, 1938, it may be of value to glassmen to secure a copy of the agreement. Copies may be obtained from the United States Tariff Commission, Washington, D. C.

Japan: Exports of glass products (exclusive of plate glass, mirrors, bracelets, beads and thermos bottles) during March, 1938, were reported by the Japan Glass Trade Association to be 4,129,203 dozens worth Yen 1,208,768, an increase of 497,526 dozens worth Yen 230,565 over exports in February. However, the March figures were 579,148 dozens and Yen 395,146 below the March, 1937, exports.

On the other hand, judging from a report by the Osaka Glass Manufacturers Guild, many of their members face bankruptcy because of the upward trend of raw material prices. Production costs are said to have advanced 30 to 40 per cent as compared with pre-war price level.

Indicative of the trend towards self-sufficiency in raw materials is the patent applied for by one Shunchiro Hirasawa for a process for producing transparent wrapping paper from glass wool. The material is said to resemble cellophane in appearance.

The Asahi Glass Co., which has done considerable expanding and development work during the past year, has decided to establish a Yen 1,000,000 subsidiary (The Tokai Mining Co.) to engage in the mining of silica in the province of Izu.

* From a report entitled "Foreign Markets for American Glass During 1937," by Edward J. Detgen, Specialties Division, Bureau of Foreign and Domestic Commerce.

EQUIPMENT AND SUPPLIES

NEW SIMPLEX LEHR

Frazier-Simplex, Inc., Washington, Pa., is now marketing a "Ready Heat" unit, straight annealing lehr of the continuous type. Offered with belt widths of 2, 3, 4, 5, or 6 feet, the new lehr is said to provide the same quality of design and construction as other Simplex annealing equipment at a lower installation cost. The lehr is furnished with a steel, unit-type outer shell and is fuel fired. The belt is a continuous woven wire conveyor and positive combustion control is secured through the use of an alloy-steel exhauster. In the design of the equipment provision is made for hand or automatic-stacker feeding. It is stated that the lehr will handle successfully any glass article that is adaptable to the use of a continuous annealing oven.

UNLOADING DRY SAND

Blaw-Knox Co., Pittsburgh, reports that they have developed a special roller gate bucket to avoid waste due to bucket leakage or scattering by wind in the unloading of fine dry silica sand from car to storage bin. This roller gate bucket is placed by hook into the sand car and there loaded by means of a clamshell. The load is then carried to the bin chute and the bucket discharged by hand operation of the roller gate. The conical shape of the bucket and regulation of the size of the opening is said to guarantee controlled and waste free discharge Buckets are made in sizes up to eight cubic yards capacity.

• The International Nickel Co. has opened a new field office in the Grant Building, Pittsburgh, to be under the direction of H. V. Beasley. The main function of this office will be to promote applications of nickel alloy steels and stimulate applications of nickel cast irons and the use of nickel in nonferrous alloys.

BULLETINS RECEIVED

George Gorton Machine Co., Racine, Wis. The 1938 edition of the Gorton Instruction Book and Parts Catalog for all pantograph machines contains 40 pages of text and charts in which glass mould makers will find much detailed information on the making of copy, masters and models in various suitable materials. Three-dimensional work is discussed. The book includes additional data on the grinding and use of cutters, particularly single-flute cutters which have proved most efficient for the smaller and more complex moulds.

Harbison - Walker Refractories Co., Farmers Bank Building, Pittsburgh, Pa. Entitled "Super-Duty Brick for Super-Duty Service," a new folder describes the features and use of Alamo and Varnon brands of super-duty fireclay brick, together with the factors which led to the development of these refractories. Test data are included.

Laclede-Christy, St. Louis, Mo. A new glass refractories stock list gives information about a great variety of shapes and sizes carried in stock at St. Louis and Toledo.

Cyclone Fence Co., Waukegan, Ill. An eight-page illustrated booklet gives much information about the construction and installation of metal conveyor belts. Both chain link, woven and flat-strip belt are covered.

Homestead Valve Mfg. Co., Inc., Coraopolis, Pa. Valve reference Book No. 38 describes and illustrates boiler blow-off valves, lift-plug valves, and a variety of other types. Included are dimensions, tables, suggested uses and suggested metals for specific installations.

Harnischfeger Corp., 4400 W. National Ave., Milwaukee. Bulletin R-5 gives complete and specialized information on Smootharc welding electrodes.

• The O. Hommel Co., Pittsburgh, have recently moved their New York offices from 421 Seventh Ave. to 200 West 34th St., New York City.

NEW STRAIN TESTER

An entirely new polariscopic strain tester, said to be the most sensitive of its kind, has just been announced by the Polaroid Corporation, Boston. Designed to specifications of the Testing Committee of the Glass Container Association, it is adaptable either for high precision laboratory requirements or for routine plant inspection.

The operator views the test objects through a binocular eyepiece against a powerful light source. The field is 10 inches in diameter to accommodate containers up to one gallon size; smaller sizes can be viewed simultaneously for comparison. The entire polarizing assembly is protected from breakage by a thick sheet of unbreakable transparent plastic and is mounted in shock-absorbing gaskets.

Strains appear in brilliant colors, said to be more intense than has ever been possible before, enabling the operator to inspect pieces with minimum eye fatigue. Another feature is that by the use of polaroid strain testing spectacles, several observers can view an object at the same time permitting quick observation and discussion.

CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

Base Materials

		Carlots	Less Carlots
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	43.00	46.00
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Borax ($Na_2B_4O_7 10H_2O$)	lb.	....	....
Granulated	In bags, lb.	.0215	.027 -.0295
Powdered	In bags, lb.	.024	.0295-.0232
Boric acid (H_3BO_3) granulated	In bags, lb.	.048	.054 - .0565
Calcium phosphate ($Ca_3(PO_4)_2$)	lb.	.07	.07½
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.0875	.0925
Synthetic (Artificial)	lb.	.0825	.0875
Feldspar—			
20 mesh	ton	11.00-13.25	
40 mesh	ton	11.50-13.75	
Granular	ton	11.75-14.00	
Semi-granular	ton	11.00-13.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	30.00	....
In bags	ton	31.60	38.00-40.60
Kryolith (see Cryolite)			
Lead Oxide (Pb_3O_4) (red lead) (N. Y.)	lb.	.065	....
In 5 Ton lots	lb.	....	.07
Less than 5 Tons	lb.	....	.075
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	....
Burnt (CaO) ground, in bulk	ton	7.00	....
Burnt, ground, in paper sacks	ton	9.00	....
Burnt, ground, in 280 lb. bbls.	Per bbl.	2.25	2.25
Potassium carbonate—			
Calcined (K_2CO_3) 96-98%	lb.	.065	.0675
Hydrated 80-85%	lb.	.055	.0575
Salt cake, glassmakers (Na_2SO_4)	ton	15.00	25.00
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	.95	....
In barrels	Per 100 lb.	1.35	....
In bags	Per 100 lb.	1.10	....
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls.	Per 100 lb.	....	2.50-2.90
95% and 97%			
Bulk	Per 100 lb.	1.35	....
200 lb. bags		1.415	1.44
100 lb. bags		1.45	1.475

Special Materials

		Carlots	Less Carlots
Aluminum hydrate ($Al(OH)_3$)	lb.	....	.03½
Aluminum oxide (Al_2O_3)	lb.	.04	.05
Antimony oxide (Sb_2O_3)	lb.	.11½	.12¼
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.03	.03½
Barium nitrate ($Ba(NO_3)_2$)	lb.	....	.07¾
Lepidolite—			
Nepheline syenite—			
Pyrophyllite, Standard Grade	lb.	9.00	12.00
Rutile (TiO_2) powdered, 95%	lb.	.08½ 09½	.10-.11
Sodium fluosilicate (Na_2SiF_6)	lb.	.05¼	.06
Tin Oxide (SnO_2) in bbls.	lb.	....	.44
Zinc Oxide (ZnO)			
American process, Bags	lb.	.06¼	.06½
White Seal, 150 lb. bbls.	lb.	.08¾	.09
Green Seal bags	lb.	.08	.08¼
Domestic White Seal bags	lb.	.08½	.08¾
Red Seal, bags	lb.	.07½	.07¾
Zircon			
Refined Granular (Milled .01-.02c higher)		.06½	.07-.08
Commercial, Gran. (Milled .02¼-.02½ higher)		.02¾	.03-.03½

Coloring Materials

		Carlots	Less Carlots
Barium selenite ($BaSeO_3$)	lb.	....	1.50-1.75
(Commercial, 25% Selenium)	lb.	....	.90
Cadmium sulphide (CdS)	lb.	....	1.10-1.20
Chromite (99% through 200 mesh)	lb.	37.00	40.00
Cerium hydrate—			
100 lb. drums and 600 lb. barrels	lb.	....	.60
Chrome Oxide Green, 400 lb. bbls.	lb.	....	.22-.26
Cobalt oxide (Co_3O_4)			
In bbls. 350 lbs. or more,	lb.	....	1.67
Less than 350 lbs.,	lb.	....	1.77
Copper oxide—			
Red (Cu_2O)	lb.	....	.18
Black (CuO)	lb.	....	.14¼ -.14¾
Black prepared	lb.	....	.22
Iron Oxide—			
Red (Fe_2O_3)	lb.	....	.0425
Black (Fe_3O_4)	lb.	.04½	....
Iron Chromate	lb.	....	.035-.05
Lead Chromate ($PbCrO_4$)	lb.	....	.16
Manganese, Black Oxide			
In Paper bags	ton	57.50	60.50-65.50
In Burlap bags	ton	59.50	62.50-67.50
In Casks	ton	61.50	64.50-69.50
Neodymium oxalate, 50 lb. drums	lb.	....	3.50
Nickel oxide (Ni_2O_3), black	lb.	....	.35-.40
Nickel monoxide (NiO), green	lb.	....	.35-.40
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	.03¾	.09-.09¼
Powdered	lb.	....	.09½-.09¾
Potassium Chromate (K_2CrO_4) 100 lb. kegs	lb.	....	.27
Powder blue	lb.	....	.2075-.2125
Rare earth hydrate—			
100 lb. drums	lb.	....	.35
325 lb. barrels	lb.	....	.30
Selenium (Se) In 100 lb. lots	lb.	....	2.00
In lesser quantities	lb.	....	2.10
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	.06¾	.07-.07¼
Sodium chromate (Na_2CrO_4) Anhydrous	lb.	.08¼	.08½
Sodium selenite (Na_2SeO_3)	lb.	....	1.80-2.00
Sodium uranate (Na_2UO_4) Orange	lb.	....	1.50-1.55
Yellow	lb.	....	1.50-1.55
Sulphur (S)—			
Flowers, in bbls.	Per 100 lb.	3.35	3.70-4.10
Flowers, in bags	Per 100 lb.	3.00	3.35-3.75
Flour, heavy, in 250 lb. bbls.	Per 100 lb.	2.90	3.25-3.65
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	....	2.25-2.30
Yellow orange	lb.	....	1.50-1.55

Polishing Materials

		Carlots	Less Carlots
Emery, Turkish	lb.	....	.07
Pumice Stone,			
American Ground Italian FFF, FF, F	lb.	....	.03
0, 0½, ½, 1.	lb.	....	.03¼
Putty Powder	lb.	....	.38-.42
Rotten Stone	lb.	....	.03
Rouge, Red	lb.	....	.14
Black	lb.	....	.16

PROPERTIES OF GLASS STONES

(*Continued from page* 275)

corundum is soluble in glass with difficulty it persists in the glass as a stone. In time the face of the refractory block gradually becomes converted (Fig. 13) into a sponge-like network of corundum crystals which, if subjected to conditions in which spalling is likely to occur, may throw corundum stones.

Below the glass line a somewhat similar reaction takes place. According to the system Al_2O_3-SiO_2 (Fig. 14), mixtures containing more than 55 per cent Al_2O_3 dissociate into corundum and liquid at 1810°C. However, molten glass will react with the refractory or clay substance with the formation of corundum and liquid at temperatures below 1550°C, even when the refractory or clay contains less alumina than the theoretical ratio, Al_2O_3-$2SiO_2$.

Since the extent of the reaction above the glass line is different from the reaction below the glass line it is possible to determine microscopically the point of origin of the corundum stones. Small crystals (0.002-0.08 mm.) having rounded edges and associated in some cases with fine grained amorphous particles, or else with small needles of mullite, usually have their origin at points below the glass line. Large crystals (0.1-2 mm.) having well defined edges originate from points above the glass line. In addition, corundum crystals from above the glass line (Fig. 15) are often embedded in dark-colored (brown or blackish) glass nodules or knots. In both cases nephelite may be associated with the corundum.

A few copies left*

GLASS TANK FURNACES

By Samuel R. Scholes

The only book in the English language devoted entirely to glass tank furnaces, it describes the most modern practices relating to design, construction, operation, behavior and economy of glass tanks.

An interesting and useful book for both the plant executive and technologist.

THE GLASS INDUSTRY
11 West 42nd Street, New York, N.Y.

*Orders for books originally intended for Japan have had to be cancelled due to difficult regulations recently imposed. The last few copies are therefore available. The price, $3.50, foreign, $4.00. Orders should be mailed promptly to THE GLASS INDUSTRY.

GORILLA LIVES IN GLASS HOUSE

In order to protect Gargantua, their 450-lb. female gorilla, from weather changes—and to protect the public from her ferocious onslaughts—the Ringling Brothers circus have literally packaged their precious monster in glass. Herculite glass made by the Pittsburgh Plate Glass Co. is used. The cage, constructed by an air-conditioning company, is 26 feet long and 6 feet high (inside). From the ground to the top it measures about 12 feet and weighs more than 10 tons. The glass sheets are lined inside with bars. Two plates of glass sealed in a frame with "dead air" space in between, because of its insulating properties, reduces the transmission of heat or cold. This also prevents variations in outside and inside air temperatures from "steaming up" the glass.

BOOK REVIEW

Agenda (1938) *pour Verrerie Ceramique Emaillerie Cimenterie*, par Jacques Wolf M., Editions "Ceremver", Bruxelles, Belgium.

This is the fifth edition of *Agenda*. *Agenda* is something between a desk day by day diary, and a *vade mecum* of miscellaneous notes on mensuration, chemical formulae, etc. In this edition there is a digest of titles of recent, or more or less recent, articles in the technical press, on subjects of interest to glass, clay, enamel, and cement workers. The selection appears to be somewhat haphazard.—F.W.P.

• The Thatcher Manufacturing Co. recently completed repairs on No. 3 tank at its Elmira, N. Y., plant and production was resumed on June 21. No change in the design of the 90-ton tank was made and the work was done by the Thatcher organization. The company is now operating three tanks at the Elmira plant.

• October 27, 1939, has officially been designated as National Glass Distributors' Association Day at the Golden Gate International Exposition on San Francisco Bay. There will be elaborate special events, ceremonies and displays.

• Francis C. Flint, chief chemist of the Hazel-Atlas Glass Company, is reported to be moving his offices from Zanesville, Ohio, to Wheeling, West Virginia.

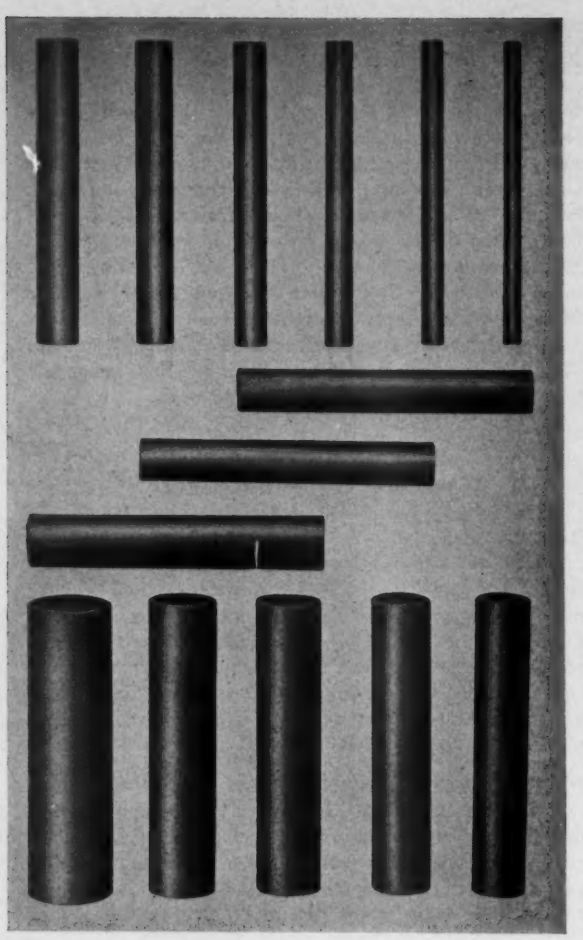
• H. S. Brady, formerly with the Hazel-Atlas Glass Co., is now general manager of the Jeannette Glass Co., Jeannette, Pa.

THE SHARP-SCHURTZ COMPANY

CHEMISTS AND CONSULTING ENGINEERS

FOR THE GLASS INDUSTRY

LANCASTER, OHIO U. S. A.



Round Bar Sticks of Gunite

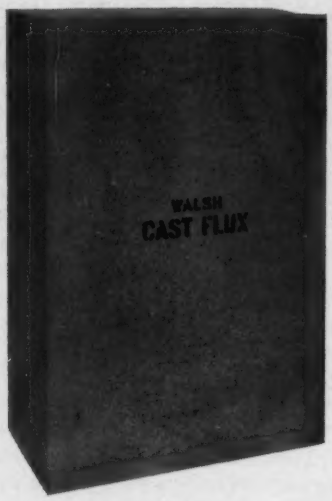
INCREASED savings in manufacturing costs are assured through the use of Gunite castings. Perfected after years of research and testing under actual operating conditions, it has been proven that Gunite offers four or five times the life of ordinary glass mould iron.

Excellent thermo-conductivity, resistance to heat fatigue and freedom from foundry defects are just a few of the established values of Gunite. Gunite has just the right smoothness, hardness and polish—producing lustrous, smooth ware unusually free from defects.

Our eighty years of experience in metallurgy insure you the utmost in glass moulds and mould parts. Send for booklet describing analysis and complete line of Gunite glasshouse castings.

GUNITE FOUNDRIES CORPORATION
ROCKFORD ILLINOIS
Established 1854

WALSH CAST-FLUX



The Vacuum-cast flux block of superior quality.

Walsh Cast-Flux blocks are machine-trued to exact size and shape after burning.

THEY LAST LONGER

The excellent results obtained in numerous tanks melting various types of glass has definitely established the efficiency and economy of Walsh Cast-Flux blocks.

Walsh Cast-Flux has a dense, uniform structure; it is burned at higher temperatures, is thoroughly bonded and possesses a low coefficient of expansion.

Walsh Cast-Flux blocks meet the most rigid requirements for tanks operating at higher temperatures . . . they insure greater tonnage, higher quality glass, freedom from defects, longer life and maximum economy.

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Manufacturers of Refractories for the glass industry for over 50 years

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MODELS
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Quality and Quick Service
....350 EMPLOYEES
OVERMYER
MOULD COMPANY
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SUPPLIERS OF ALL CERAMIC NEEDS

GLASSMAKERS
Chemicals—Colors
SUPPLIES

A complete line of quality materials
Immediate shipments

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PRODUCTS

Two-way Economy in a New SOLVAY Offering!

NOW —a *domestic* Dustless Calcined Potassium Carbonate that assures *economy in transportation costs* through absence of water of crystallization, and *economy in heat* otherwise required to drive off this water in the glass furnace or pot.

SOLVAY
Dustless Calcined
98-100%

POTASSIUM CARBONATE

Also Granular Hydrated 83-85%

•

GROUND CAUSTIC POTASH
New—but this SOLVAY product is already setting the same high standard in the Glass Industry as that attained by

SOLVAY
DUSTLESS DENSE
SODA ASH

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Have you enough moulds?

Mould costs have been so much reduced by Gorton Duplicators that it pays now to have several identical moulds on hand. This saves in moulding operations and prevents any chance of holding up production of glassware for lack of moulds to work with.

The tool rooms of the glass industry like Gortons because they are easy to operate and maintain, and produce accurate work with least time and effort.

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BOTTLES

FULL AUTOMATIC
MACHINE PROCESS

Whitall Tatum Company

Manufacturers Since 1836

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Flashed Opal Blown Sheet Glass
Colonial Antique Colored Glass
Heat-Ray Resisting (Cool Glass)
"TWIN-RAY" — the scientific illuminating glass.

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"IF IT'S MADE OF GLASS, ASK US FIRST"

THE OTTAWA SILICA COMPANY

OTTAWA. ILLINOIS

ETERNAL AS THE SANDS OF TIME

The PRINCE of GLASS SANDS — The Diamond OTTAWA WHITE SAND

THREE PLANTS TO SERVE YOU

OPERATING YEAR AROUND

CRYSTAL SILICA 99% PURE

Laclede Christy

SAINT LOUIS

Our files contain the records of 3,380 tests on clays and minerals. We designed and built the first and largest test furnace exclusively for testing glass house refractories. We have maintained a Mellon Institute Fellowship for 20 years . . all for the benefit of Glass Manufacturers.

V-673

BINNEY

MIN-OX

For manufacturing economy plus increased sales

Min-ox, made exclusively for glass moulds, gives the ware an unusual clarity and brilliance—thereby increasing sales appeal. And, too, Min-ox practically eliminates fire-finishing, reduces cleaning costs and spoiled ware, and generally lowers production costs.

Min-ox has been proved to bring greater sales—greater manufacturing economies—greater profits.

If you are not getting the finest possible ware with the greatest possible economy, ask about Min-ox moulds. We shall be glad to send you complete details.

BINNEY

THE BINNEY CASTINGS COMPANY
TOLEDO, OHIO
originators of alloys for glass molds

YOUR MIXING PROBLEMS
are different!

therefore you need *specially designed* glass batch mixers.

Standard mixers mean standard results. It takes super-mixers by Ransome to give you the edge on competition. Write for the facts.

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CONCRETE MACHINERY CO.
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Since 1850 **Ransome** **SPECIALIZED MIXERS**

CALCIMAG
PATENTED

A CLINKERED DOLOMITE FOR THE GLASS BATCH...

Calcimag is granular... stands up in storage. It is uniform... reduces segregation. It is easy to handle... your men will like it. It melts more easily... lowers production costs.

GLASS BATCH

BASIC DOLOMITE INCORPORATED
HANNA BUILDING
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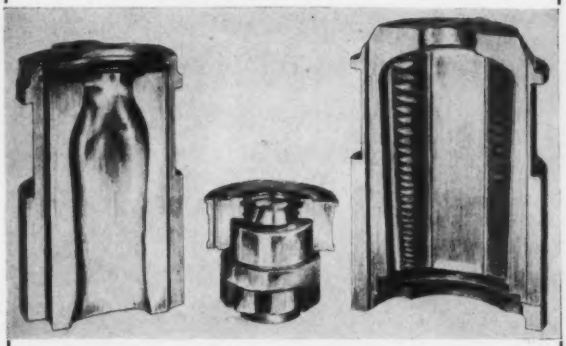
Engineering



• Properly designed and accurate moulds are a very important factor in a glass factory in insuring good production. The wide range and length of experience our Engineers have had in designing moulds for the various machines has enabled our moulds to go into production with a minimum amount of expense and loss of time.

THE TOLEDO MOULD COMPANY
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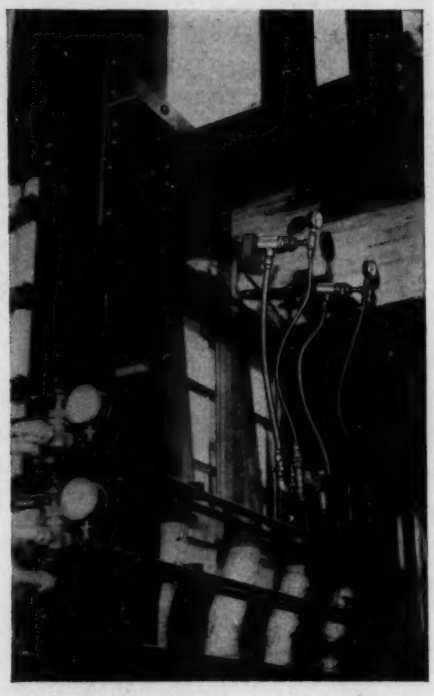
Toledo, Ohio, U.S.A.

TECO

Oil Fired Furnaces



TECO'S patented design places the oil directly into the furnace.

Note the jack arch burner block construction and the method of mounting the burners below the ports. The burner block arch is independently supported above the flux walls. The curved arch port bottom allows the burners to be readily adjusted or removed.

The TECO Oil firing design has been incorporated in side fired and end fired furnaces and can be adapted to your existing furnaces.

Glass Plant Engineers specializing in Furnaces, Lehrs and auxiliary plant equipment

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BALTIMORE, MD.

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TOLEDO, OHIO

● Looking at the world thru dark glasses may protect your eyes from the light temporarily, but it will cause you to miss seeing many worthwhile things.

● Consider for example the buyer or manufacturer who buys annealing and decorating lehrs on price alone.

● The reputation of **SIMPLEX** lehrs has been built solely on a quality basis. Keep in step with glass manufacturing progress thru **SIMPLEX** equipment.

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